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How we Lost 90% of Participants on a Bad Bet: Results from a Pilot Randomized Controlled Trial on Cognitive Bias Modification in Problem Gamblers.

Authors:
Leroy Snippe[1,4], Marilisa Boffo[2], Harriet Galvin[1,2], Ronny Willemen[3], Thomas Pronk[1], Geert Dom[4] & Reinout W. Wiers[1,5]

Affiliations:

1. Addiction Development and Psychopathology (ADAPT) Lab, Department of Psychology, University of Amsterdam, Amsterdam, Netherlands.
2. Department of Psychology, Education and Child Studies (DPECS), Erasmus University Rotterdam, Rotterdam, Netherlands.
3. ZorGGroep Zin vzw, Genk, Belgium.
4. Collaborative Antwerp Psychiatric Research Institute (CAPRI), University of Antwerp (UAntwerp), Wilrijk, Belgium.
5. Centre for Urban Mental health, University of Amsterdam

Corresponding author:
L. Snippe
l.snippe@uva.nl
Department of Psychology, University of Amsterdam
Nieuwe Achtergracht 129
1018 WS, Amsterdam, The Netherlands

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Conflict of interest

All authors declare they have no conflicts of interest.

Ethics

The study protocol was approved by the Medical Ethics Committee of the University of Antwerp (October 2014, Belgian registration number: B300201422158) and by the Ethics Committee of the University of Amsterdam (August 2014, Protocol number: 2014-DP-3774). Changes in design or experimental procedure, including the addition of the follow-up qualitative study approved by both ethics review boards.
Netherlands Trial Register: NTR5096

Highlights

- This study explored the effectiveness of new, easily-accessible, low-threshold stand-alone digital interventions in PG, which have previously shown promising results in SUD.
- The study encountered high attrition and did not generate support for the interventions.
- Qualitative data affirms the approach of the interventions shows promise whilst also suggesting potential improvements to increase adherence.

1. Abstract

Whilst opportunities to participate in gambling have increased, access to support for problem gamblers is lacking behind. This unbalance calls for improved and accessible intervention methods. This double-blind RCT explored the effectiveness of two interventions targeting automatic cognitive processes, known as Attentional Bias Modification (AtBM) and Approach Bias Modification (ApBM). It was hypothesized these interventions would reduce gambling behavior and reduce or reverse targeted biases.

Participants (N = 331) were community-recruited Flemish (35%) and Dutch (65%) adult problem gamblers motivated to reduce or stop their gambling who received either six sessions of active training (AtBM or ApBM) or of the corresponding sham-training (sham-AtBM or sham-ApBM).

Due to the high attrition rates (90.1% at the intervention phase), the study was terminated before completion since it would greatly limit the validity of any results. A post hoc qualitative study was performed on a subset of participants to gain insight into contributing factors for this attrition rate. Issues negatively impacting participants' motivation to complete the program were identified, as well as elements of the program that received approval.

The results from this study provide a first insight into the potential of the use of online CBM as an intervention in PG. Suggestions and directions for future studies are discussed.

Keywords (6)
Problem Gambling; Gambling Disorder; Cognitive Bias Modification; Attentional Bias Modification; Approach Bias Modification; online interventions.

2. Abbreviations used

PG	Problem Gambling
CBM	Cognitive Bias Modification
AtBM	Attentional Bias Modification
ApBM	Approach Bias modification
VPT-a/t	Visual Probe Task; Assessment/Training version
AAT-a/t	Approach-Avoidance Task; Assessment/Training version
EGM	Electronic gaming machine
SUD	Substance use disorder
RT	Reaction time
CBT	Cognitive Behavioral Therapy

3. Introduction

Problem gambling (PG) affects millions of people globally every year, [1] with devastating personal and societal consequences. In addition, only a small number of problem gamblers seek treatment, which is estimated to be as few as 10% [2,3], similar to treatment-seeking rates in SUDs [4,5]. Reasons for such low uptake are thought to relate to unawareness and inaccessibility of treatment options, stigma, and shame [6,7].

In the wake of the COVID-19 pandemic, more gamblers have been moving away from land-based casinos towards online environments, and an increase in PG-escalation has been observed in some (but not all) at-risk groups [8–10]. Hence, an extension of available intervention tools and modalities is warranted to address these challenges. To this end, accessible, anonymous, self-guided and low-cost online interventions have gained interest. These programs have generally been shown to be acceptable, cost-efficient and moderately effective in reducing PG symptomatology [11–14]. However, there do seem to be limitations, and self-guided programs have been found to be less effective than 'traditional' face-to-face treatment options [15,16].

So far, most online PG intervention programs have focused on deploying digital versions of cognitive-behavioral interventions, targeting primarily motives, cognitions, and explicit goal-oriented behavior. However, automatic habitual behavioral patterns have been mostly ignored, even though they have been demonstrated to play a role in addiction [17–20] , albeit the extent of which is under debate [21–23].

It should be noted that a strict separation between explicit and implicit cognitive processes in addiction, such as postulated in dual-process theories [24,25], has given way to more flexible and dimensional theories [26–28], emphasizing the temporal dynamics of information processing and the gradual shift from habitual to reflective processing of information. That being said, automatically activated habitual behaviors are rooted in implicit cognitive processes supposed to reinforce and maintain addictive behaviors through a vicious cycle of biased information processing, affecting decision-making (i.e., cognitive bias). Two such biases studied extensively in addiction [29], are the attentional bias and the approach bias.

The attentional bias refers to the selective allocation of attention toward emotionally salient cues. In the case of PG this means gambling-related cues will attract and hold attention to a greater extent than emotionally neutral stimuli do. The approach bias on the other hand, describes an automated behavioral action tendency to approach, in the case of PG, gambling-related cues. Together, these biases could lead to habituated addictive behavior (problem gambling) even in the light of perceived negative consequences [30].

Some evidence for the existence of cognitive biases within PG has been found for both attentional [31–37] and, to a lesser extent, approach bias [38]. The precise manner in which these biases impact PG remains a topic of investigation, but both craving and impulsive behavior seem to play important roles, where the relation between craving and PG is mediated by the attention bias [39], and the relation between attentional bias and PG is both mediated and moderated by impulsivity [33,40].

Based on such research, the possibility of deploying cognitive bias modification (CBM) training as a PG-intervention to reduce or reverse such gambling-related biases could be explored. CBM training generally consists of adapted cognitive bias assessment tasks, such as the visual probe task (VPT[41]) or approach-avoidance task (AAT[42]), where a stimulus-response contingency is added to train participants to learn a new, more functional associative response towards gambling cues (i.e., shift attention away from or avoid gambling-related cues). Interventions using CBM training have been shown moderately effective in reducing symptomatology across psychopathologies, including addiction [43,44], anxiety [45] and food disorders [46], although mixed and null results have been reported as well [47,48],[49]. However, despite its potential, research on CBM in PG is very scarse [50], with one pilot trial as a notable exception [51]. This latter study suffered from a common issue in online CBM research, namely a high attrition rate [52,53].

One suggested solution to the problem of attrition in online CBM is to tailor the training by making sure the cues employed are relevant to the participant. More specifically, images utilized in CBM training for problem gamblers should depict gambling games that participants play regularly [55]. Additionally, adherence is also thought to be improved when CBM interventions use motivational interviewing techniques, which further boost treatment motivation and adherence [56–58].

This report presents the results of a pilot randomized controlled trial (RCT) exploring the effectiveness of a tailored online PG-intervention including either attentional bias modification (AtBM) or approach bias modification (ApBM), combined with an automated motivational feedback intervention to boost adherence and motivation to treatment [62]. Main outcomes included changes in gambling frequency and expenditure and the targeted biases (i.e., attentional or approach bias) over the medium term. In addition to the pre-registered quantitative study, a follow-up qualitative analysis of participants' experience with the study and the intervention was carried out at the conclusion of the study to better understand study attrition and intervention non-usage (i.e., [59]).

4. Method

4.1. Participants

Participants were Dutch and Belgian adult gamblers seeking help for gambling problems, community-recruited through self-help websites, online gambling forums, social media and promotion meetings around local addiction-care facilities. Participants were included when being 18 years or older, speaking Dutch, Flemish or French, currently seeking help for gambling problems, having gambled at least twice in the previous 6 months, and with daily Internet access. To increase external validity, no eligibility criteria were based on the severity of gambling problems or concomitant treatment regimes.

A conservative sample size analysis yielded an estimate of 182 participants (see (Boffo et al. 2017)), accounting for a maximum attrition rate of 60%. If the attrition rate would exceed this percentage, a precise analysis of the available data would be inficiated and the full-scale RCT using the current study design would be infeasible; hence, the pilot study would be discontinued. The information available would then be used to make suggestions on improvement of the study design.

Recruitment began in February 2015 and ended February 2018, when an inspection of attrition rate showed that 90.9% of participants dropped out during the intervention phase.

4.2. Study design

The study is a pilot online double-blind RCT with a four-group parallel design: two groups completed either version of the cognitive bias training (AtBM or ApBM), and two control groups completed a sham version of either training. Before participants were able to register, they were informed of the goals of the study and were made aware of the experimental nature of the interventions. After registration, eligibility screening and informed consent, participants were randomly allocated (stratified by gender) to one of the four conditions through the program website and completed a baseline assessment including demographics data and a battery of clinical and neurocognitive measures (see SPIRIT Table 1), followed by tailored motivational feedback to reduce or quit gambling.

Participants completed 6 training sessions consisting of short tailored motivational feedback, a pre-training bias assessment, and the assigned training version. Participants could train almost daily and received regular email reminders to participate. A follow-up assessment took place online at conclusion of the training and after 3 and 6 months (see the CONSORT flowchart in Figure 2).

Primary outcomes were actual gambling behavior, as operationalized as past gambling frequency and gambling expenditure, using an ad-hoc scale. The time frame assessed was 12 months for the baseline assessment and 1 month for both the post- and follow-up assessments (to account for potential overlap). Secondary outcomes were attentional bias for gambling stimuli (Visual Probe Task - assessment version, VPT-a; [60]) and approach bias for gambling stimuli (Approach-Avoidance Task - assessment version, AAT-a; [61]).

For full details on study design, materials and procedures, we refer the reader to the published study protocol [62].

	Study Period						
Time points	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**3-month follow-up**	**6-month follow-up**
Enrolment							
Eligibility screening	x						
Informed consent	x						
Baseline assessment	x						
Allocation	x						
Interventions							
ApBM training	♦	—	—	—	♦		
AtBM training	♦	—	—	—	♦		
Sham ApBM	♦	—	—	—	♦		
Sham AtBM	♦	—	—	—	♦		
Assessment							
<u>*Baseline variables:*</u>							
Demographics	x						
DSM5	x						
Feedback questions	x						
BIS-11	x						
AUDIT/CORE	x						
RSES	x						
<u>*Primary outcomes:*</u>							
Gambling frequency	x				x	x	x
Gambling expenditure	x				x	x	x
<u>*Secondary outcomes:*</u>							
Approach bias (AAT-a)	♦	—	—	—	—	♦	
Attentional bias (VPT-a)	♦	—	—	—	—	♦	
<u>*Other variables:*</u>							
Stroop task	x						
G-RCQ	x						
Motivation to train	♦	—	—	—	♦		
FOCUS	♦	—	—	—	—	—	♦
Gambling details	x						
BDI-II	x				x	x	x
SOGS	x				x	x	x

Fig.1 SPIRIT Figure; Schedule of forms and procedures per study time-point, adapted from [63].

ApBM = approach bias modification, AtBM = attentional bias modification, DSM5 = itemisation of DSM5 diagnostic criteria for gambling disorder, BIS-11 = Barratt Impulsiveness Scale, AAT-a = Approach Avoidance Task - assessment version, VPT-a = Visual Probe Task - assessment version, AUDIT = Alcohol Use Disorder Identification Test, CORE= Core-Institute Alcohol and Drug Survey, RSES = Rosenberg Self-Esteem Scale, BDI-II = Beck Depression Inventory-II short, SOGS = South Oaks Gambling Screen, G-RCQ = Gambling Readiness to Change Questionnaire, FOCUS = ad-hoc scale for assessing the level of concentration during the task

4.3. Intervention

The active CBM interventions consisted of the training version of either the VPT for AtBM or the AAT for ApBM depending on the allocated condition. The VPT [60] is a reaction-time task aimed at measuring attentional bias for specific cues (i.e., gambling-related or neutral images). In the training version, participants were consistently trained to direct their attention away from gambling cues by manipulating the cue-response contingency. In the assessment and sham training versions, the response cue was presented in equal proportion on both gambling-related and neutral stimuli, whereas in the training version, only on neutral stimuli.

The AAT [64–66] is another reaction-time task where participants are required to 'approach' (keypress [pull] to enlarge the cue, mimicking approach) or 'avoid' (keypress [push] to shrink the cue, mimicking distancing from the cue) a gambling-related or neutral cue based on the image orientation (i.e., tilted left or right). In the training version, participants had to 'push' away 100% of gambling cues; whereas in the sham and assessment versions of the task this percentage was set at 50%.

Stimuli were a set of 40 matched image pairs of neutral and gambling-related cues including five categories of gambling games (roulette and dies, electronic gaming machines (EGM), card games, sports betting, Belgian bingo), used to tailor the intervention stimuli to the participants' preferred gambling activities.

All participants received tailored motivational feedback on the individual negative consequences of gambling and the benefits of reducing or abstaining from gambling,. The feedback message was presented at baseline and the start of each training session, together with the chosen reasons to quit/abstain and related benefits. A full description of the interventions and stimuli is included in the study protocol [63].

4.4. Outcomes

As primary outcome measures, changes in gambling behavior were assessed with a scale measuring gambling frequency and expenditure in the previous 12 months at baseline, the previous month at the post-intervention assessment, and the previous 3 months at both follow-ups.

Secondary outcomes included changes in gambling attentional and approach bias measured with the VPT-a and AAT-a, respectively. A relative attentional bias score was computed by subtracting the median response time (RT) for gambling trials (cued by gambling-related stimuli) from the median RT for neutral trials (cued by neutral stimuli) [52]. Similarly, a relative approach bias score was computed by subtracting median RTs for pull trials from push trials per cue category (gambling and neutral [52]). In both instances, a positive score would indicate the presence of a bias towards gambling-related cues.

Other exploratory measures included changes in depressive symptomatology and severity of gambling problems [52,63]. However, given the available data (see Results section), the analyses were limited to the primary and secondary outcomes.

4.5. Data analysis

Data preparation and preprocessing are described in Appendix B. All baseline variable distributions were screened for normality assumptions and univariate outliers. Each training group was compared to its control group to check for baseline differences in demographics and clinical characteristics (see Table 1).

Due to the substantial amount of missing data, the pre-specified analyses [67] were not possible. Instead, mixed linear models (MLM) were used to use all data available and account for the covariance across time points. All analyses were conducted in R with the '*lme4'* package (version 1.1.15 [68]). For each outcome measure, the model first included the random intercept only and the intraclass correlation (ICC) value was inspected for MLM appropriateness (range of .15 to .30, typical of psychology literature [69]). The pairwise comparison for each training type was entered as the main predictor for all outcomes. Adjusted models controlled for baseline variables significantly correlated with the outcome of interest or when unbalanced between conditions. Covariates were retained within the model when shown to serve as significant predictors.

4.6. Exploratory qualitative post hoc analysis

After terminating the study, an exploratory post-hoc qualitative study was launched between January and April 2018 to better understand the program's acceptability and the high attrition rate. Semi-structured phone interviews with participants selected from the RCT sample were conducted by a trained Psychology research masters student, who was not involved in the main RCT and with a basic level of theoretical knowledge of CBM interventions. Participants were recruited via a purposive sampling procedure. The initial sample was divided into four subgroups based on meaningful study process markers: baseline drop-out before or after ApB/AtB assessment, drop-out during training period, and study completers. From each subgroup, 10 participants were randomly invited to participate, stratifying for severe vs low-to-moderate gambling severity, gender, and gambling preferences, to maximize result transferability. Recruitment continued until the required sample size per subgroup was reached or until the initial sample was depleted.

After participants responded and gave informed consent, a 30-minute semi-structured phone interview was conducted. The interviewer followed a script focusing on three predetermined themes related to the intervention program: content, delivery method, and adherence. The theme '*content*' was designed to assess the appropriateness, relatability and clarity of the program';s content (e.g. stimuli and instructions). The theme of '*delivery*' assessed the perceived accessibility an anonymity of the program, as well as how participants perceived the self-guided nature. The theme of '*adherence*' assessed how motivating (to continue with the progam), relevant and burdening (taxation) participants experienced the program to be. Please see Appendix A for an overview of themes, sub-themes and probing questions. Participants received compensation in the form of a book (worth €20).

Interviews were audio-recorded, transcribed verbatim and anonymized, after which the original recording was destroyed. Transcripts were analyzed and coded using thematic analysis [70] in ATLAS.TI. The transcribed texts were coded according to a mixed deductive-inductive approach, using the predetermined themes whilst allowing for theme revision or inclusion of new themes emerging from the data. Coding accuracy was assessed using Krippendorff's alpha coefficient by having a second coder (first author, a gambling addiction psychotherapist, PhD candidate, expert in CBM interventions and involved in the main RCT) independently code 5% of the transcripts at random. Inter-rater reliability was found to be acceptable for the purpose of this study (Krippendorff 2013), although the limited set of data combined with an extensive framework of themes and subthemes might have negatively impacted it (percentage of agreement = 80.7%, Krippendorff α = 0.73).

Even though great care was put into maintaining a certain level of neutrality in preparing and conducting the interviews, we were aware of the (potential) influences of reflexivity (Olmos-Vega et al. 2022; Dodgson 2019). For example, in regards to personal relfexivity, much of the design of the qualitative analysis (i.e. constructing themes, subthemes, leading questions and interview scripts) was done by the first author with a background as a therapist and researcher. Hence, it can be expected much emphasis was put on elements of behavioral change and of methodology, which did not necessarily match the experiences by participants. Being aware of this, elements were put in place to counter or account for reflexivity effects, including consulting other researchers and therapists on the research design, having an interviewer who herself was relatively inexperienced (and unbiased) the the topic of PG, by allowing (new) topics to emerge from the transcripts and by the independent (partial) coding. Furthermore, we expected stigma and the dynamic between researcher and participant to have possible reflexivity effects. This played a role in deciding to conduct the interviews via the phone, since we felt this was the best way to ensure a certain degree of anonymity for the participants.

5. Results

5.1. Sample description

The final sample comprised 331 participants (41.7% female, mean age = 33.64, SD = 11.21) with moderate to severe levels of gambling problems (mean SOGS = 9.10, SD = 3.41). 83% (n = 271) had gambled on average once per week or more over the past 12 months, 89.1% (n = 287) spent on average ≥ €500 per month on gambling over the past 12 months, and 85.7% (n = 276) spent ≥ €500 on gambling over the past month (see Table 1 for detailed sample characteristics). No significant differences in baseline characteristics for demographics, gambling problems, alcohol use and gambling behavior emerged.

[Table 1 here]

On average participants completed 1.51 sessions (SD = 2.50), including baseline (see Figure 2 and Table 2), with no significant differences across conditions ($F_{(3,327)} = 0.19$, $P = 0.91$). Only 9.1% (n = 30) of the total sample completed all 6 training-sessions, 8.8% (n = 29) the post-assessment, 3.9% (n = 13) the 3-month follow-up, and 1.5% (n = 5) the 6-month follow-up. Retention rates did not differ significantly across conditions, except at 3-month follow-up: the sham-AtBM condition retained 5.5% (n = 4) of the initial sample, whereas the AtBM condition retained 1 participant (n = 1) (P = .03, two-tailed Fisher's exact test).

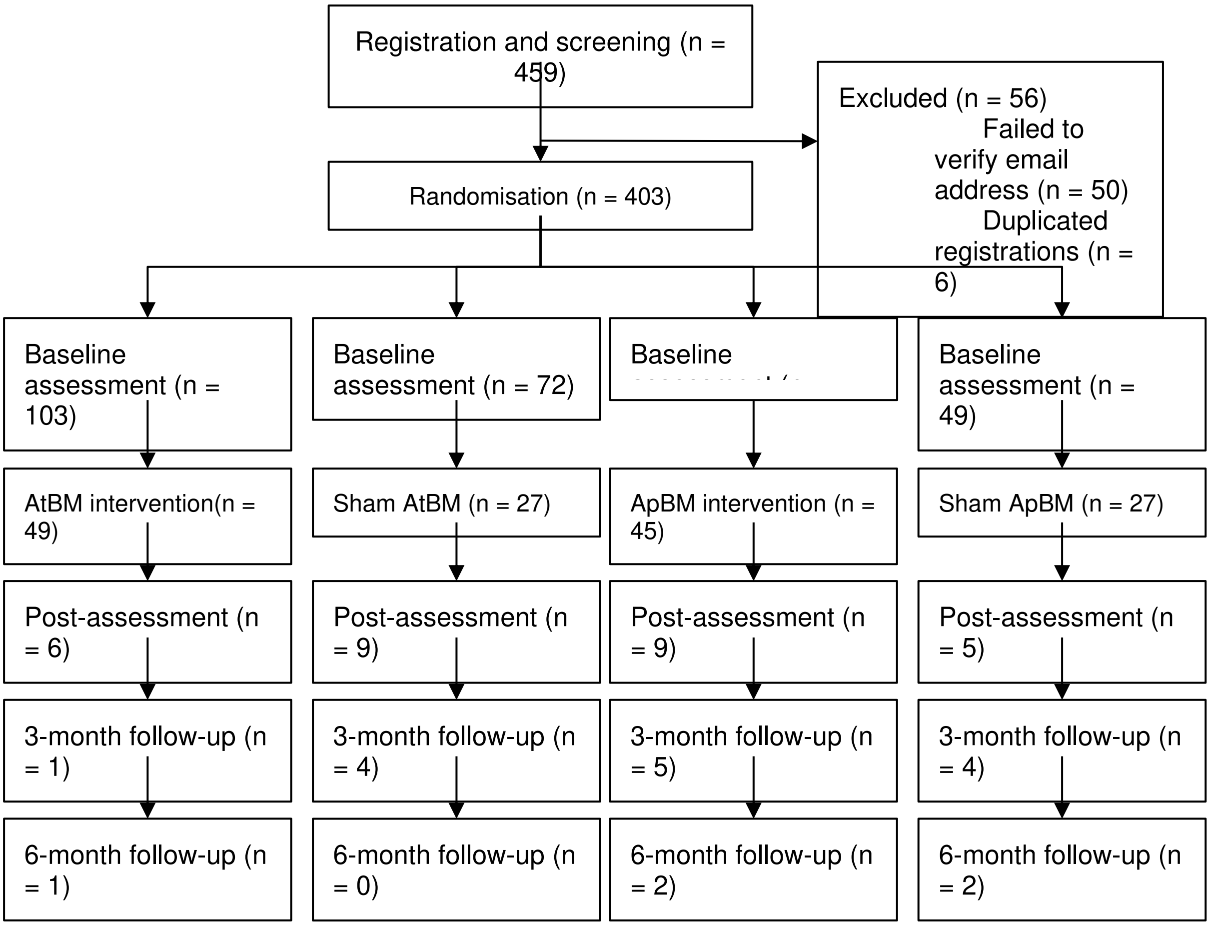

FIGURE 2. CONSORT participant flow diagram.

[Table 2 here]

5.2. Main outcomes analysis

Table 3 reports the summary statistics of all outcomes by condition and time phase. There were no significant differences in baseline scores on any outcome measure across conditions.

[Table 3 here]

5.2.1. ApBM comparison

For *gambling frequency,* only language was included as a covariate ($t_{(144)} = -3.30$, $P < .001$) (see Table A1 in Appendix C). No significant effects emerged in the final model (Table 4). For *gambling expenditure*, only marital status was retained ($t_{(147)} = -2.07$, $p = .04$; (see Appendix C, Table A2) and no significant effects emerged in the final model (Table 4).

For both *attention* and *approach bias*, the ICC analysis did not endorse MLM use (ICC < 0.01). However, to account for the within-subjects covariance we opted for MLM with the “keep it maximal” correction, i.e., fit the most complex model consistent with the experimental design, removing only terms required to allow a non-singular fit [71]. For *attentional bias*, the DSM5 score was retained in the model despite not being a significant predictor ($P = .33$) to preserve model integrity. For both outcomes, neither model yielded significant results for the active ApBM training (Table 4; Appendix C, Table A5 and A6).

5.2.2. AtBM comparison

The 6-months follow-up was not included in the models for *gambling frequency* and *expenditure,* due to the presence of n = 1 participant only. For *gambling frequency,* only language was retained in the final model ($t_{(175)} = -3.62$, $p < .001$; see Appendix C, Table A3). No significant effects emerged in the model (Table 4). For *gambling expenditure,* the SOGS score was included ($t_{(165)} = 4.61$, $p < .001$; see Appendix C, Table A4) and only a significant main effect was found for Time Point ($F_{(3, 18)} = 4.60$, $p = 0.02$; see Table 4).

For both *approach* and *attention bias*, no covariates were included and neither model yielded significant results for the active AtBM training (Table 4; see Appendix C, Table A7 and A8).

[Table 4 here]

5.3. Qualitative results

All participants were approached to be interviewed and only four agreed to a phone interview (see Table 5). Three of them completed the entire study, which makes the qualitative sample less representative of the original sample but does allow for feedback on all program elements.

Table 5: Participants' characteristics in the qualitative study: Gender, Adherence Status and Total Scores for Variables of Interest

Participant	Age	Gender	Adherence	SOGS	Preferred gambling activity
A	46	female	Completer	7	EGM
B	30	male	Drop-out	7	Roulette & dices, EGM
C	49	male	Completer	14	Roulette & dices, EGM
D	47	male	Completer	11	Card games, (Belgian) Bingo

Overall, participants rated the intervention *content* as appropriate. None of the participants reported any difficulties with the language or understanding the instructions. There were mixed opinions about the relatability of the stimuli (gambling and neutral images) since the use of land-based gambling cues made the images less relatable for online gamblers (and vice-versa).

5.3.1. Content

The interviews brought to light an important limitation regarding the *relatability* of the used stimuli (gambling and neutral images). Especially the decision to not differentiate between online- and land-based gambling games and to combine online and land-based cue images, seems to have negatively impacted the relatability of the content. As one participant put it:

"When I was gambling online, I used to see different images than the ones used in the program. In the program, there were images with casinos, so that did not suit my situation."

(participant A)

Besides the relatability, however, participants rated the *appropriateness* and *clarity* of the content as sufficient. None of the participants reported any difficulties with the language or understanding of the instructions.

5.3.2. Delivery method

In regards to the delivery method, participants primarily commented on *self-guidance*. More specifically, they reported experiencing the intervention as being 'superficial', primarily due to a lack of personal contact. Several participants indicated they would have preferred a hybrid form of intervention, combining self-guided training elements with contact with a mental health care professional. As one participant put it:

"If you want the program to succeed, it would be helpful if you could press on a "chat button", so that you take action when you want to be helped. This would have great value in my opinion."

(participant B)

The participants did, however, appreciate the degree of autonomy and freedom the program offered (e.g. when and where to complete their sessions) within certain limits. One participant reported these features helped maintain their intrinsic motivation to change their gambling behavior:

"I liked that the program was non-binding and without obligations. You have to stay motivated when you want to be helped. It's good that they don't tell you what you have to do."

(participant B)

In regard to *accessibility,* all interviewees reported the program to be easily accessible and readily available at any time and valued these characteristics in approval of the online format. Participants also reported trusting their *anonymity* to be guaranteed, their data to be handled with care and the personal details required to participate to be adequate. Participants reported no need for the program to be available for mobile devices. One reason was the fact that their homes offered a relatively distraction-free environment to participate.

5.3.3. Adherence

In regard to adherence, interesting insights were gained from the interviews. Even though the majority of the interviewees were program completers, they all were critical of the *relevance* of the program. Whilst the participant who dropped out actually indicated this was the main reason for them to stop participating in the program, other participants also commented on the demotivating effect this lack of relevance had on them:

"*I had to look the whole time at those images. And I thought: "Why am I doing this?*"

(participant C)

These comments indicate the program likely suffered from low face validity. Even though participants were informed of the nature of the interventions before registration, this procedure might not have been effective in adequately informing and preparing them. This is especially troublesome since the nature of CBM is rather repetitive and unchallenging, stressing the importance for relevance to motivate participants to continue the program.

Furthermore, in regards to *taxation*, even though participants reported being motivated to participate and willing to invest time and effort, they reported the duration and monotone nature of the training tasks demotivated them. Again, participants seemed insufficiently prepared for this and found it demotivating. As one participant put it:

"[The training] was really long. Really long! It costs a lot of time. I do get that it is necessary, but maybe it is useful to clarify even more for the user why it is taking so long"

(participant B)

These factors greatly negatively impacted the *motivation* experienced by participants to complete the program. That being said, some of the participants did find the program motivating by its ability to create awareness of the nature of their PG behavior. It was thus experienced as a 'stepping stone' on the road to recovery. As two participants put it:

"I appreciated the program because it helped me to face reality"

(participant A)

"[The program helped me to reach my goals] because I was more aware of my behavior when gambling"

(participant D)

In conclusion, doubts about the effectiveness and purpose of the intervention coupled with a perception of overly lengthy and repetitive training sessions, were the main factors in participants not feeling motivated to adhere to the program.

6. Discussion

This study represents the first attempt to explore the effectiveness of two online, stand-alone CBM interventions with automated tailored guidance in reducing PG behavior in adult problem gamblers. No intervention effects on PG behavior or targeted cognitive biases were found, despite the use of tailored motivational feedback and tailored stimuli to boost study adherence, the current study suffered from high attrition rates, which is relatively common in online CBM studies [52,53,72] and in PG-interventions in general [73]. . As such, the study could not be completed as originally intended [63] limiting the reliability and validity of the results. A post-hoc qualitative analysis was added to the research design. Although the sample for the qualitative analysis was small and biased, it still provided valuable information on reasons for dropping out and ways in which online CBM research designs and interventions could be improved.

Qualitative results pointed at the (long) duration and tedious nature of the CBM intervention as a potential factor contributing to the high attrition rate. Indeed, this is an issue that has been put forward by other researchers [52,53] and several suggestions have been made to counter this, including improvements on the design of the CBM interventions themselves as well as the addition of motivation-enhancing elements. Two of these suggested elements, tailoring and automated motivational feedback, were employed in the current study to boost study-adherence. This approach, however, did not result in an acceptable attrition rate. The tailoring was done by including five types of gambling cues to match game-type preferences of participants in order to maximize the cues' relevance as well as salience [74]. However, this approach was likely too limited because it did not adequately account for the broad diversity in the gambling games landscape, especially failing to differentiate between online and land-based gambling. This is especially relevant since a growing body of research hints at important differences (e.g. socio-demographical and gambling-behavioral) between online and land-based gamblers [75–82]. If the matching of the cues to the game-type preferences of participants was inadequate, this would have reduced the perceived relevance of the intervention to the participants, negatively impacting their motivation to complete the program. This was indeed reported to be the case by interviewees.

Furthermore, the motivational feedback was perceived as 'superficial'. Hence, it may have lacked relevance as well, and have failed to trigger participants' intrinsic motivation to complete the program. Indeed, the motivational feedback was designed to be fully automated and was only tailored to a limited degree in order to be available and applicable to a broad sample. However, it appears the motivational feedback missed its mark, possibly even achieving an opposite effect.

The qualitative results indicated the self-guided nature of the program was perceived as a double-edged sword. On the one hand, interviewees praised it for increasing intrinsic motivation to change their gambling behavior. On the other hand, they expressed they missed personal contact, explaining that the lack thereof negatively influenced their motivation to complete the program. This resonates with results showing self-guided programs to be less effective than face-to-face interventions [83], possibly related to the lack of (professional) human support [84].

Contrastingly, interviewees did approve of the online format and administration of the program, appreciating how this increased accessibility and availability. Interviewees also greatly valued their anonymity in participating in the program. This indicates online (CBM) interventions do hold potential in reducing the barrier for seeking treatment for problem gamblers, if designed, employed, and supported correctly.

The above underlines the importance of striking the right balance between automation and a broad availability on the one hand, and personalization on the other, in designing online PG interventions and preventing attrition. This is especially true for CBM interventions. Future studies should explore whether adding automated yet more dynamic and tailored motivational feedback to CBM interventions, as well as the usage of adequately tailored CBM cues, offers better adherence results.

Results from this study stress the importance of conducting pilot studies; these can speed up the development of new designs and interventions and pave the way for more complex and large-scale RCTs [85–87]. Pilot studies also help to minimize the risks for participants in RCTs testing novel, experimental interventions.

The current study could be argued to have been too complex to be an effective pilot study, which is emphasized by its inability to adapt to, account for and explain the high attrition rate. This argues for future pilot studies to reduce the complexity of the study design and adopt more flexible and adaptive designs, such as the Leapfrog Design [88,89].

In addition, the current study also highlights the value of qualitative research, especially in the domain of novel state-of-the-art intervention design. Even though the qualitative sample was biased, the qualitative analysis yielded information that could not have been derived otherwise. Furthermore, if qualitative methods (e.g., focus groups) would have been employed earlier on in the study design to support its development and actively include the feedback of its target group, this might have provided the opportunity to identify weaknesses in the study design and for making adjustments, before committing to the quantitative data gathering phase. As such, the usage of qualitative methods across different stages of the empirical cycle should be promoted further [90,91].

On the quantitative part of the study, the null results are aligned with previous studies administering CBM via the internet in SUD's [52,53,92–95] and gambling [96]. This trend might indicate that administering CBM interventions via the web is not as effective as administering on site, or that CBM is mostly effective as an add-on intervention as opposed to a being a stand-alone intervention. This does indeed seem to be the current consensus, although conflicting evidence does exist [103]. More research is needed however, especially research directly comparing the different modalities of administration.

This pilot study yielded important results on the potential of online CBM interventions in PG. Future studies should continue to explore the effects of this class of interventions in PG and to improve on the study design by incorporating suggestions derived from the present study. These include improvements on the design of CBM interventions to promote motivation and the use of appropriate research methods, such as pilots, qualitative or mixed methods, and adaptive designs.

Interesting options for promoting motivation and boosting adherence include, besides previously discussed tailoring and motivational feedback, gamification and monetary incentivization. Gamification has been described as promising [104] and is already being used in commercially available CBM applications [105]. However, results on the effect of elements of gamification on motivation are mixed [106,107], and some evidence even indicates they can limit the effectiveness of CBM retraining [107]. Another option, monetary incentivization, has a history in SUD treatment, and monetary-based abstinence reinforcement interventions are amongst the most effective available interventions in drug-abuse treatment [108]. In support of its use in boosting adherence in PG, a currently ongoing study in which online CBM is combined with tailored motivational feedback and monetary incentives (vouchers for an online store) does indeed show substantially larger retention rates (Snippe et al., 2019). A complicating and potentially controversial factor however, is how to safely incentivise problem gamblers with monetary incentives whilst not inducing gambling behavior or trigger a relapse. In the previously mentioned study (Snippe et al., 2019) this was done by providing incentives in the form of vouchers that were only redeemable in an online store that did not provide gambling-related products or services. Finally, the inclusion of task feedback or progress reports along the training sessions to boost adherence is another, uncommon feature of CBM interventions that warrants exploration.

Furthermore, it would be interesting to see whether earlier discussed options of motivational feedback and tailoring can be improved upon. For example, is the addition of personal contact effective in boosting adherence? We are aware of one ongoing study combining web-based CBM training combined with online therapist-guided CBT in problem gamblers [109]. Secondly, the use of appropriate, recognizable and tailored stimuli has been emphasized by previous studies [55,110][,96]. Fully personalized cues directly uploaded by participants could be a solution to maximize salience and familiarity of training stimuli, although this would open logistical challenges when matched target and neutral cues are desired as is the case for AtBM interventions.

An important open question regarding the potential for (online) CBM interventions in PG that should be addressed by future research, is that of possible interactions between CBM effects and adherence and, amongst others, craving and impulsivity. Impulsivity has been shown to be a strong correlate of both PG [111–114] and cognitive biases in addiction disorders [115]. There is evidence that the relationship between cognitive biases and PG is influenced by impulsivity, where the greater a person's impulsivity, the stronger the link between cognitive biases and PG [33,40]. This seems to imply that CBM as an intervention for PG, might especially be beneficial for persons who score high on impulsivity. Indeed there is some evidence supporting this hypothesis from research in addiction- and eating disorders [116–118], whilst conflicting results do exist [65].

One important issue however, is that impulsivity also appears to increase chances of dropping out of treatment prematurely, both in SUD's [119] and PG [120–125]. This seems to be especially true in internet-based treatments in general [126] and in PG in specific [127]. These results combined paint a paradoxical picture for online CBM interventions in PG, where the persons who would potentially benefit most from the intervention, have a lower chance of actually completing it. Adding to this paradox are interactions found between impulsivity, craving and cognitive biases [36,128–130] and results on cue-induced craving in PG [130–132]. These results suggest the possibility that presenting problem gamblers with gambling cues, might induce craving, as well as increase impulsivity. This in turn, might increase chances of premature drop-out (and hence the administration of a sub-optimal dosage of CBM) and even of relapsing. This raises important questions and ethical concerns, which overlap with previously raised questions, including whether or not, at this stage, CBM should be studied as a stand-alone intervention without therapist support, especially in an online environment. Furthermore, it is an argument in support of tailoring and sub-grouping of PG, perhaps amongst personality traits such as impulsivity.

Finally, in regard to the CBM intervention itself, future studies should aim to improve the research paradigms and methodology. Several authors claim that a sham training version, as used in the current study, is a sub-optimal control condition to determine clinical effects [52,133–135]. An alternative method has been proposed, based on automatic inference learning, which always includes personalized stimuli and is conceptually closer to cognitive behavioral therapy [136,137].

In conclusion, the study did not find evidence for the effectiveness of an online stand-alone CBM program with automated tailored guidance for problem gamblers in reducing PG behavior and retraining cognitive biases. The main problems concerned the high attrition rates and methodological issues. A qualitative post hoc-analysis offered some insights into how the program was experienced and on possible contributing factors for the high attrition, with a positive confirmation on the use of low-threshold self-guided online programs to lower the barrier to access help and support gamblers in tackling problems while keeping their anonymity. Despite the null results, we believe this study has been a valuable lesson learned, generating suggestions to improve upon the research design and the design of online CBM interventions in PG.

7. References

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Table 1. Baseline characteristics of the final sample (N = 331) and per condition.

Characteristics	**ApBM (n = 107)**	**Sham ApBM n = 49)**		**AtBM (n = 103)**	**Sham AtBM (n = 72)**		**Overall Sample (n = 331)**	
Age (years), mean (SD)	31.50 (10.54)	35.39 (12.90)	U = 2186.5, P = 0.11	34.41 (10.64)	34.56 (12.26)	U = 824.5, P = 0.61	33.64 (11.21)	$H_{(3)}$ = 6.27, P = 0.11
Language, n (%)			$\chi 2_{(1)}$ = 2.5 , P = .11			$\chi 2_{(1)}$ = 0.71 , P = .40		$\chi 2_{(3)}$ = 4.60 , P = .23
Dutch	77 (71.96)	29 (59.18)		61 (59.22)	48 (66.67)		215 (64.95)	
Belgian	30 (28.04)	20 (40.82)		42 (40.78)	24 (33.33)		116 (35.05	
Highest education, n (%)			$\chi 2_{(1)}$ = 0.42, P = .52			$\chi 2_{(1)}$ = 0.69, P = 0.41		$\chi 2_{(3)}$ = 1.93 , P = .59
< Bachelor’s degree	67 (62.62)	28 (57.14)		55 (53.40)	43 (59.72)		193 (58.31)	
≥ Bachelor’s degree	40 (37.38)	21 (42.86)		48 (46.60)	29 (40.28)		138 (41.69)	
Marital status, n (%)			$\chi 2_{(1)}$ = 1.27, P = .26			$\chi 2_{(1)}$ = 0.28, P = .59		$\chi 2(3)$ = 3.41 , P = .33
Married	18 (16.82)	12 (24.49)		28 (27.18)	17 (23.61)		75 (22.66)	
Other	89 (83.18)	37 (75.51)		75 (72.82)	55 (76.39)		256 (77.34)	
Average monthly income n (%)			P = 0.20			$\chi 2_{(1)}$ = 0.24, P = .63		$\chi 2_{(3)}$ = 4.02 , P = .26
<3000	101 (94.39)	43 (87.76)		89 (86.41)	64 (88.89)		297 (89.73)	
≥3000	6 (5.61)	10 (12.24)		14 (13.59)	8 (1.11)		34 (10.27)	

Joint monthly income n (%)			$\chi2_{(1)} = 1.15$, $P = .28$			$\chi2_{(1)} = 0.46$, $P = .5$		$\chi2_{(3)} = 1.61$, $P = .67$
<3000	67 (62.62)	35 (71.43)		65 (63.11)	49 (68.06)		216 (65.26)	
≥3000	40 (37.38)	14 (28.57)		38 (36.89)	23 (31.94)		115 (34.74)	
Gambling frequency (12-m) n (%)								
≥ Once per week	22 (20.75)	9 (19.57)		33 (33.00)	31 (43.66)		52 (16.10)	
< Once per week	84 (79.25)	37 (80.43)		67 (67.00)	40 (56.34)		271 (83.01)	
Gambling expenditure (12-m) n (%)								
<500€	11 (10.38)	9 (19.56)		9 (9.00))	9 (12.86)		35 (10.87)	
≥500€	95 (89.62)	37 (80.43)		91 (91.00)	61 (87.14)		287 (89.13)	
Gambling expenditure (1-m) n (%)								
<500€	15 (14.15)	6 (13.04)		13 (13.00)	13 (18.57)		46 (14.29)	
≥500€	91 (85.85)	40 (86.97)		87 (87.00)	57 (81.43)		276 (85.71)	
DSM5, mean (SD)	6.85 (1.95)	5.76 (2.28)	$U = 2709$, $P < .01$*	6.34 (2.21)	6.24 (2.26)	$U = 3168$, $P = 0.78$	6.41 (2.17)	$H_{(3)} = 8.56$, $P = 0.04$**
BIS-11, mean (SD)	70.66 (8.58)	73.54 (9.69)	$t_{(72)} = -1.3$, $P = 0.2$	71.23 (10.19)	69.11 (9.48)	$t_{(79)} = 0.91$, $P = 0.37$	71.01 (9.49)	$F_{(3, 151)} = 0.98$, $P = 0.41$
AUDIT[ı], mean (SD)	6.48 (5.57)	5.24 (4.41)	$U = 1968.5$, $P = 0.35$	6.78 (6.92)	6.24 (6.12)	$U = 2255.5$, $P = 0.87$	6.36 (5.99)	$H_{(3)} = 0.90$, $P = 0.83$
CORE (Alcohol), mean (SD)	5.54 (3.88)	5.22 (3.90)	$U = 1816.5$, $P = 0.69$	4.98 (3.86)	5.57 (4.04)	$U = 2044.5$, $P = 0.38$	5.32 (3.89)	$H_{(3)} = 1.58$, $P = 0.66$

RSES, mean (SD)	15.25 (2.25)	15.71 (1.76)	$t_{(73)}$ = -0.87, P = 0.39	15.47 (2.00)	15.43 (2.10)	U = 769.5, P = 0.78	15.43 (2.05)	$F_{(3, 152)}$ = 0.27, P = 0.84
BDI, mean (SD)	7.86 (4.57)	7.86 (4.57)	$t_{(71)}$ = -1.45, P = 0.15	8.11 (3.87)	6.64 (4.14)	$t_{(79)}$ = 1.59, P = 0.12	7.97 (4.26)	$F_{(3, 150)}$ = 1.93, P = 0.13
SOGS, mean (SD)	9.64 (3.22)	9.48 (3.99)	$t_{(144)}$ = 0.65, P = 0.52	8.57 (3.35)	9 (3.34)	$t_{(165)}$ = -1.05, P = 0.29	9.10 (3.41)	$F_{(3, 109)}$ = 1. 75, P = 0.16
Stroop-Task, mean (SD)	-43.54 (115.33)	-4.93 (107.74)	$t_{(65)}$ = -1.32, P = 0.19	-66.31 (84.35)	-52.92 (91.91)	$t_{(74)}$ = -0.64, P = 0.52	-47.17 (101.01)	$F_{(3, 139)}$ = 1. 96, P = 0.12
G-RCQ, mean (SD)	-4.60 (3.24)	-4.00 (2.76)	U = 524, P = 0.51	-4.75 (3.09)	-4.07 (2.58)	U = 666.5, P = 0.43	-4.47 (3.00)	$H_{(3)}$ = 1.25, P = 0.74

One-way analysis of variance was conducted to test baseline differences on continuous variables across the 4 conditions; Kruskal-Wallis tests were conducted to determine differences at baseline for non-normally distributed data across all 4 conditions; Chi-square tests were conducted to test baseline differences on categorical variables across the 4 conditions and for comparing training groups (i.e., AtBM, ApBM) to their respective control group (i.e., sham AtBM, sham ApBM); Mann-Whitney U Tests were conducted to determine differences at baseline for non-normally distributed data comparing training groups (i.e., AtBM, ApBM) to their respective control group (i.e., sham AtBM, sham ApBM); Fisher's extract tests were used in cases of reduced sample size.
AtBM: attentional bias modification condition; ApBM: approach bias modification condition; DSM5: itemized DSM5 PG diagnostic criteria; BIS-11: Barratt Impulsiveness Scale; AUDIT: Alcohol Use Disorders Identification Test; CORE: CORE alcohol use questionnaire, short version, CORE Institute; RSES: Rosenberg Self-esteem Scale; BDI: Beck Depression Inventory-II, short version; SOGS: South Oaks Gambling Scale; G-RCQ: Gambling Readiness for Change Questionnaire.
*p ≤ .05, **p ≤ .01, ***p ≤ .001

Table 2. Study retention details per condition and for the full sample.

Session	ApBM (n = 107)	Sham ApBM (n = 49)	AtBM (n = 103)	Sham AtBM (n = 72)	Overall Sample (n = 331)

All Sessions, mean (SD)	1.49 (2.50)	1.69 (2.84)	U = 2527.5, P = 0.69	1.40 (2.13)	1.60 (2.79)	U = 3938.5, P = 0.44	1.51 (2.50)	$F_{(3,327)}$ = 0.19, P = 0.91
Baseline, n, %	45 (42.05)	22 (44.90)	$\chi2_{(1)}$ = 0.11 , P = 0.74	49 (43.20)	27 (37.50)	$\chi2_{(1)}$ = 1.75 , P = 0.19	143 (43.20)	$\chi2_{(3)}$ = 1.87, P = 0.60
Training 1, n, %	29 (27.10)	13 (26.54)	$\chi2_{(1)}$ = 0.01 , P = 0.94	30 (26.39)	19 (37.50)	$\chi2_{(1)}$ = 0.16 , P = 0.69	91 (27.49)	$\chi2_{(3)}$ = 0.21, P = 0.98
Training 2, n, %	20 (18.69)	12 (24.49)	$\chi2_{(1)}$ = 0.69 , P = 0.41	23 (22.33)	14 (19.44)	$\chi2_{(1)}$ = 0.21 , P = 0.65	69 (20.85)	$\chi2_{(3)}$ = 0.92, P = 0.82
Training 3, n, %	16 (14.95)	8 (16.33)	$\chi2_{(1)}$ = 0.05 , P = 0.83	14 (13.59)	11 (15.28)	$\chi2_{(1)}$ = 0.1 , P = 0.75	49 (14.80)	$\chi2_{(3)}$ = 0.22, P = 0.97
Training 4, n, %	14 (13.08)	7 (14.29)	$\chi2_{(1)}$ = 0.04 , P = 0.84	8 (7.77)	12 (16.67)	$\chi2_{(1)}$ = 3.32 , P = 0.07	41 (12.39)	$\chi2_{(3)}$ = 3.45, P = 0.33
Training 5, n, %	9 (8.41)	5 (10.20)	P = 0.77	7 (6.80)	10 (13.89)	$\chi2_{(1)}$ = 2.43 , P = 0.12	31 (9.37)	P = 0.44
Training 6, n, %	10 (9.35)	5 (10.20)	P = 1	6 (5.83)	9 (12.50)	$\chi2_{(1)}$ = 2.41 , P = 0.12	30 (9.06)	P = 0.47
Post, n, %	9 (8.41)	5 (10.20)	P = 0.77	6 (5.83)	9 (12.50)	$\chi2_{(1)}$ = 2.41 , P = 0.12	29 (8.76)	P = 0.45
FU1, n, %	5 (4.67)	4 (8.16)	P = 0.46	1 (0.97)	4 (5.56)	P = 0.03*	13 (3.93)	P = 0.02*
FU2, n, %	2 (1.87)	2(4.08)	P = 0.59	1 (0.97)	0 (0.00)	P = 1	5 (1.51)	P = 0.34

One-way analysis of variance was conducted to compare study retention among all groups across all time points; Chi-square tests were conducted to test differences in study retention at each time-point comparing training groups (i.e., AtBM, ApBM) to their respective control group (i.e., sham AtBM vs sham ApBM); Fisher's extract tests were used in cases of reduced sample size; Mann-Whitney U Tests were conducted to compare training groups (i.e., AtBM, ApBM) to their respective control group (i.e., sham AtBM, sham ApBM) for differences in study retention across all time points.
AtBM: attentional bias modification; ApBM: approach bias modification; Post: post-training assessment; FU1 and FU2: follow-up assessment at 3- and 6-months.
$^{*}p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$

Table 3. Summary statistics on outcomes by condition and for the full sample.

Outcomes and assessment timen points	**ApBM**	**Sham ApBM**		**AtBM**	**Sham AtBM**		**Overall Sample**	
Gambling frequency, mean (SD)			U =1974.5, P = 0.06			U = 3783, P = 0.35		$H_{(3)}$ = 5.42, P = 0.14
Baseline (past 12-m)	6.38 (1.51)	6.87 (1.20)		6.80 (1.05)	6.50 (1.53)		6.61 (1.36)	
Post (past 1-m)	2.33 (1.66)	2.20 (2.28)		1.60 (1.51)	1.33 (1.73)		1.86 (1.74)	
FU1 (past 3-m)	0.86 (0.90)	1.50 (1.52)		3.33 (0.58)	2.00 (1.87)		1.67 (1.49)	
FU2 (past 3-m)	4.5 (0.71)	3.0 (2.83)		2.0 (NA)	NaN		3.4 (1.82)	
Gambling expenditure, mean (SD)			U = 2679, P = 0.20			U = 3783, P = 0.35		$H_{(3)}$ = 4.19, P = 0.24
Baseline (past 12-m)	9.20 (1.97)	9.04 (1.89)		9.21 (1.83)	8.81 (2.11)		9.11 (1.95)	
			U = 2452, P = 0.95			U = 3857.5, P = 0.17		$H_{(3)}$ = 0.57, P = 0.90
Baseline (past 1-m)	8.20 (2.50)	8.35 (2.22)		8.33 (2.31)	8.07 (2.47)		8.24 (2.40)	

Post (past 1-m)	9.00 (1.41)	8.67 (1.15)		8.33 (0.58)	6.60 (3.36)		8.17 (2.15)	
FU1 (past 3-m)	6.00 (3.92)	9.25 (0.5)		10.00 (0)	7.50 (1.91)		8.07 (2.58)	
FU2 (past 3-m)	9.5 (0.71)	9.5 (0.71)		8.0 (NA)	NaN		9.2 (0.84)	
Approach Bias (AAT) *Relative*, mean (SD)			*U* = 609.5, *P* = 0.49			*U* = 1162.5, *P* = 0.07		$H_{(3)}$ = 4.01, *P* = 0.26
Baseline	-17.99 (99.61)	5.96 (57.10)		6.01 (70.65)	-13.31 (91.84)		-5.26 (83.44)	
Post	9.83 (15.74)	-13.60 (73.81)		5.75 (27.34)	0.06 (44.02)		1.91 (40.04)	
FU1	-35.40 (57.76)	-15.88 (23.98)		NaN (NA)	8.36 (29.63)		-15.92 (42.78)	
Attentional Bias (VPT) , *Relative* mean (SD)			$t_{(83)}$ = 0.56, *P* = 0.57			*U* = 798.5, *P* = 0.39		$H_{(3)}$ = 4.54, *P* = 0.21
Baseline	-0.33 (49.77)	-6.89 (51.59)		-28.31 (67.19)	12.88 (55.85)		-13.13 (58.31)	
Post	-48.33 (81.12)	6.10 (21.84)		14.17 (41.64)	18.94 (39.51)		-5.14 (59.93)	
FU1	4.20 (63.15)	-20.38 (56.15)		-40.50 (NA)	30.25 (31.04)		1.42 (52.12)	

One-way analysis of variance was conducted to test baseline differences on continuous variables across the 4 conditions; t-tests were conducted to test baseline differences comparing training groups (i.e., AtBM, ApBM) to their respective control group (i.e., sham AtBM, sham ApBM); Kruskal-Wallis tests were conducted to determine differences at baseline for non-normally distributed data across all 4 conditions; Mann-Whitney U Tests were conducted to determine differences at baseline for non-normally distributed data comparing training groups (i.e., AtBM, ApBM) to their respective control group (i.e., sham AtBM vs sham ApBM).
Post: post training assessment; FU1 and FU2: follow-up assessment at 3- and 6-months; AAT: Approach-Avoidance Task; VPT: Visual Probe Task.
$^{*}p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$

Table 4. Results of MLM analysis: primary (gambling frequency and expenditure) and secondary outcomes (relative approach and attentional bias scores)

		Gambling Frequency	Gambling Expenditure	Relative Approach Bias	Relative Attention Bias
ApBM Comparison					
	Time Point	$F_{(2, 49.50)} = 0.51$, $P = 0.60$	$F_{(3, 24.21)} = 0.90$, $P = 0.45$	$F_{(2, 17.74)} = 1.71$, $P = 0.21$	$F_{(2, 81.53)} = 0.74$, $P = 0.48$
	Condition (active vs sham)	$F_{(1, 133.18)} = 0.17$, $P = .068$	$F_{(1, 73.58)} = 0.04$, $P = 0.84$	$F_{(1, 99.45)} = 0.06$, $P = 0.80$	$F_{(1, 54.12)} = 0.44$, $P = 0.51$
	Time Point x Condition	$F_{(2, 49.33)} = 0.33$, $P = 0.72$	$F_{(3, 24.27)} = 1.50$, $P = 0.24$	$F_{(2, 17.74)} = 0.81$, $P = 0.46$	$F_{(2, 81.92)} = 2.23$, $P = 0.11$
AtBM Comparison					
	Time Point	$F_{(3, 39.04)} = 0.05$, $P = 0.99$	$F_{(3, 17.66)} = 4.60$, $P = 0.02^{*}$	$F_{(2, 18.28)} = 0.82$, $P = 0.46$	$F_{(2, 17.37)} = 3.18$, $P = 0.07$
	Condition (active vs sham)	$F_{(1, 140.35)} = 0.05$, $P = 0.82$	$F_{(1, 57.17)} = 0.02$, $P = 0.89$	$F_{(1, 108.61)} = 0.48$, $P = 0.49$	$F_{(1, 52.75)} = 1.00$, $P = 0.32$
	Time Point x Condition	$F_{(3, 38.91)} = 1.16$, $P = 0.34$	$F_{(2, 17.95)} = 0.08$, $P = 0.93$	$F_{(1, 19.76)} = 0.27$, $P = 0.61$	$F_{(2, 17.37)} = 0.36$, $P = 0.70$

ApBM: approach bias modification; AtBM: attentional bias modification.
$^{*}p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$.

Appendix A

Semi-structured interview themes, sub-themes and probing questions.

Theme	Sub-theme	Probing questions (example)
Content	Appropriateness	"Did you feel the content of the program was appropriate?"
	Relatability	"Did you feel the content of the program was relatable for you?"
	Clarity	"Did you feel the program was clear and easily understandable?"
Delivery method	Accessibility	"Did you feel the program was sufficiently accessible?"
	Anonymity	"How do you feel your anonymity was being guaranteed during the program?"
	Self-guidance	"How do you feel about the extent to which your self-reliance was called upon during the program?"
Adherence	Motivating	"Do you feel the program sufficiently motivated you to complete the program?"
	Relevance	"Do you feel the program's relevance was sufficiently clear to you?"
	Taxation	"How do you feel that what the program delivered for you is in proportion to what you had to invest in time and energy?"

The script was tailored to the subgroups' level of program experience. For example, participants who dropped out during the first phase of the baseline would not be interviewed on how they experienced the training sessions.

APPENDIX B

Data & Task Preparation

The primary outcome of gambling frequency assessed at baseline utilized a scale ranging from 1-8, with participants reporting on their gambling frequency over the past 1-year. However, at the post-training assessment and both follow-up assessments, item scores ranged from 1-6, with participants reporting on their gambling frequency from the previous 1-month (post and first follow-up) and 3-months (second follow-up). As such prior to analysis item ranges were rescaled (i.e., transformed to z-scores - centered around 0) in order to facilitate comparisons across time points.

AtBM (i.e., VPT) and ApBM (i.e., AAT) indexes were computed according to the following steps: 1) practice and incorrect task trials were excluded, 2) correct responses recorded with reaction times <200ms or >2000ms were discarded (i.e., deemed as anticipatory or as timed out respectively), and 3) overall task accuracy was assessed resulting in n = 1 participants task data on the VPT at baseline being removed (i.e., error rate > 35%). Regarding the AtBM index, a within-subjects ANOVA was conducted to compare the VPT-a median reaction times for speeded detection trials against disengagement trials for the two types of stimuli at baseline (i.e., gambling vs neutral cues). The results showed that there was a main effect of probe location ($F(1, 519) = 37.14$, $p < 0.001$; RTs for gambling trials: $M = 619.04$, $SD = 96.49$; RTs for neutral trials: $M = 637.96$, $SD = 100.66$) and trial type ($F(1, 519) = 139.24$, $p < 0.001$; RTs for speeded detection trials: $M = 610.18$, $SD = 94.67$; RTs for disengagement trials: $M = 646.81$, $SD = 99.93$). However, there was no interaction effect between trial type and picture type ($F(1, 519) = 3.412$, $p > .07$). As such a combined AtB-Index was used within the secondary analysis of changes in attention bias for both the ApBM group and AtBM group.

APPENDIX C

MLM model summary for each primary and secondary outcomes

Table A1. Full MLM model for gambling frequency over time (ApBM training comparison)

Fixed effects	***B (95% CI)***	***t value (df)***	***P value***
Intercept	0.55 (0.22, 0.89)	3.28 (157.57)	< .001
Time Point (Post)	-0.10 (-0.84, 0.64)	-0.27 (49.96)	.79
Time Point (FU1)	0.19 (-0.49, 0.88)	0.56 (52.25)	.58
Time Point (FU2)	-0.64 (-1.76, 0.47)	-1.14 (40.08)	.26
Condition	-0.38 (-0.86, 0.10)	-1.56 (168.84)	.12
Condition x Post	0.22 (-0.71, 1.15)	0.47 (51.30)	.64
Condition x FU1	-0.45 (-1.38, 0.47)	-0.96 (51.71)	.34
Condition x FU2	1.01 (-0.55, 2.57)	1.27 (39.32)	.21
Language	-0.54 (-0.86, -0.22)	-3.30 (143.53)	< .001

Post: post intervention assessment phase. FU1 and FU2: follow-up assessment at 3- and 6-months. For Condition, active training was the reference category; for Language, Dutch was the reference category.

Table A2. Full MLM model for gambling expenditure over time (ApBM training comparison)

Fixed effects	***B (95%CI)***	***t value (df)***	***P value***
Intercept	9.12 (8.13, 10.12)	18.05 (148.90)	< .001
Time Point (Post)	-0.55 (-1.85, 0.74)	-0.84 (19.96)	.41
Time Point (FU1)	-0.15 (-1.30, 1.01)	-0.25 (20.34)	.81
Time Point (FU2)	-0.22 (-1.78, 1.34)	-0.28 (19.74)	.79
Condition	-0.03 (-0.82, 0.77)	-0.06 (151.01)	.95
Condition x Post	0.54 (-1.07, 2.14)	0.66 (20.12)	.52
Condition x FU1	-1.17 (-2.90, 0.56)	-1.33 (20.07)	.21
Condition x FU2	0.93 (-1.26, 3.12)	0.83 (19.65)	.41
Marital Status	-0.99 (-1.93, -0.05)	-2.07 (147.12)	.04

Post: post intervention assessment. FU1 and FU2: follow-up assessment at 3- and 6-months. For Condition, active training was the reference category; for Marital Status, married was the reference category.
Initially, the MLM model for gambling expenditure violated the assumption of homogeneity of variance. To correct for this, Cook's distance was used to determine potential outliers ($D < .05$). In order to retain as much data as possible, only the most extreme outlier was removed (n = 1; D = .69), which resolved the violation.

Table A3. Full MLM model for gambling frequency over time (AtBM training comparison)

Fixed effects	*B (95%CI)*	*t value (df)*	*P value*
Intercept	0.22 (-0.07, 0.52)	1.47 (181.03)	.14
Time Point (Post)	0.40 (-0.19, 0.98)	1.32 (53.09)	.19
Time Point (FU1)	0.12 (-0.65, 0.89)	0.30 (49.52)	.76
Condition	0.19 (-0.11, 0.48)	1.25 (185.05)	.21
Condition x Post	-0.35 (-1.33, 0.62)	-0.72 (56.90)	.48
Condition x FU1	0.16 (-1.09, 1.41)	0.25 (50.58)	.80
Language	-0.54 (-0.83, -0.25)	-3.62 (174.61)	< .001

Post: post intervention assessment. FU1: follow-up assessment at 3-months. For Condition, active training was the reference category; for Language, Dutch was the reference category.

Table A4. Full MLM model for gambling expenditure over time (AtBM training comparison)

Fixed effects	*B (95%CI)*	*t value (df)*	*P value*
Intercept	5.94 (4.86, 7.02)	10.74 (165.66)	< .001
Time Point (Post)	-1.07 (-2.01, -0.14)	-2.24 (18.25)	.04
Time Point (FU1)	0.45 (-0.58, 1.49)	0.87 (18.05)	.40
Time Point (FU2)	-1.58 (-3.54, 0.39)	-1.57 (17.58)	.13
Condition	0.22 (-0.47, 0.91)	0.63 (166.92)	.53
Condition x Post	-0.29 (-1.82, 1.23)	-0.38 (18.22)	.71
Condition x FU1	-0.15 (-1.73, 1.43)	-0.18 (18.11)	.86
SOGS	0.25 (0.14, 0.35)	4.61 (165.26)	< .001

Post: post intervention assessment. FU1: follow-up assessment at 3- and 6-months. SOGS: South Oaks Gambling Scale; for Condition, active training was the reference category.

Table A5. Full MLM model for relative approach bias cover time (ApBM training comparison)

Fixed effects	*B (95%CI)*	*t value (df)*	*P value*
Intercept	5.96 (-26.84, 38.76)	0.36 (76.67)	.72
Time Point (Post)	-35.48 (-95.60, 24.64)	-1.16 (20.50)	.26
Time Point (FU1)	-43.61 (-109.59, 22.38)	-1.30 (19.83)	.21
Condition	-23.95 (-63.62, 15.72)	-1.18 (76.67)	.24
Condition x Post	46.85 (-28.03, 121.73)	1.23 (20.68)	.23
Condition x FU1	4.74 (-82.79, 92.27)	0.11 (19.58)	.92

Post: post intervention assessment. FU1: follow-up assessment at 3-months. For Condition, active training condition was the reference category.

Table A6. Full MLM model for relative attention bias over time (ApBM training comparison)

Fixed effects	***B (95%CI)***	***t value (df)***	***P value***
Intercept	-24.05 (-63.44, 15.35)	-1.20 (104.32)	.23
Time Point (Post)	12.07 (-36.93, 61.08)	0.48 (94.47)	.63
Time Point (FU1)	-14.24 (-68.21, 39.73)	-0.52 (97.26)	.61
Condition	4.78 (-18.86, 28.41)	0.40 (107.93)	.69
Condition x Post	-61.59 (-122.41, -0.77)	-1.98 (95.59)	.05
Condition x FU1	15.75 (-55.80, 87.30)	0.43 (99.36)	.67
DSM5	2.70 (-2.72, 8.12)	0.98 (102.14)	.33

Post: post intervention assessment. FU1: follow-up assessment at 3-months. DSM5: itemized DSM5 diagnostic criteria for PG. For Condition, active training was the reference category.

Table A7. Full MLM model for relative approach bias over time (AtBM training comparison)

Fixed effects	***B (95%CI)***	***t value (df)***	***P value***
Intercept	-13.31(-39.61, 12.98)	-0.99 (92.67)	.32
Time Point (Post)	19.53 (-7.32, 46.39)	1.43 (18.16)	.17
Time Point (FU1)	16.44 (-21.20, 54.08)	0.86 (17.65)	.40
Condition	18.84 (-13.75, 51.43)	1.13 (92.98)	.26
Condition x Post	-11.66 (-55.65, 32.33)	-0.52 (19.76)	.61

Post: post intervention assessment. FU1: follow-up assessment 3-months. For Condition, active training condition was the reference category.

Table A8. Full MLM model for relative attention bias over time (AtBM training comparison)

Fixed effects	***B (95%CI)***	***t value (df)***	***P value***
Intercept	-12.88 (-34.36, 8.59)	-1.18 (92.30)	.24
Time Point (Post)	30.74 (-6.05, 67.53)	1.64 (17.40)	.12
Time Point (FU1)	28.95 (-23.26, 81.16)	1.09 (16.52)	.29
Condition	-15.43 (-41.73, 10.88)	-1.15 (92.30)	.25
Condition x Post	11.78 (-45.21, 68.77)	0.41 (20.01)	.69
Condition x FU1	-38.03(-151.41, 75.34)	-0.66 (16.67)	.52

Post: post intervention assessment. FU1: follow-up assessment at 3-months. For Condition, active training was the reference category.