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Attend to the positive while feeling anxious: The effect of state anxiety on the effectiveness of Attentional Bias Modification

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ABSTRACT

Background and objectives: Elevating state anxiety during Attentional Bias Modification (ABM) may improve its effectiveness by matching the emotional state experienced during the training with the emotional state under which it is intended that the learned pattern of attentional bias will subsequently operate. This study examined whether inducing elevated levels of state anxiety during ABM enhanced the effectiveness in modifying an attentional bias to socially threatening information.
Methods: Participants (n = 160) were randomized to a single session of attend-negative or attend-positive dot-probe training which was interspersed with either a state anxiety induction or control condition. Attentional bias was assessed post-training by means of a dot-probe task and a visual search task.
Results: ABM was effective in modifying attentional bias in the direction of the allocated training condition as assessed with a dot-probe task, but did not generalize to a visual search task. Importantly, state anxiety did not moderate ABM's training effects.
Limitations: Although the state anxiety manipulation successfully induced state anxiety, state anxiety levels were modest which potentially limited the chance to detect a moderating effect of state anxiety.
Conclusions: Although these findings suggest that inducing state anxiety during ABM does not improve its effectiveness, more studies are needed to confirm this preliminary conclusion. Future studies should examine whether larger state anxiety elevations and state anxiety manipulations that are more integrated into the ABM procedure do enhance training effects.

1. Introduction

The experience of social anxiety is marked by intense fear of being negatively evaluated by others in social situations (American Psychiatric Association, 2013). A possible maintaining factor of heightened social anxiety is an attentional bias which is characterized by selective attention for socially threatening information (Heimberg et al., 2010; Morrison & Heimberg, 2013; Rapee & Heimberg, 1997). To examine whether attentional bias is causally related to heightened social anxiety, training paradigms, referred to as 'Attentional Bias Modification' (ABM), have been designed to modify attentional biases and, in turn, examine whether they reduce symptoms of social anxiety (Heeren et al., 2015). The first studies that examined the effectiveness of ABM suggested that ABM was indeed effective in reducing social anxiety-related symptoms (e.g., Amir et al., 2009; Li et al., 2008; Schmidt et al., 2009). However, these initial positive findings were followed by studies which reported that experimental versions of ABM did not outperform control conditions in reducing attentional bias and social anxious symptomatology (Boettcher et al., 2012; McNally et al., 2013; Neubauer et al., 2013). Similarly, whereas some meta-analyses have concluded that ABM may have clinical utility as significant effects of ABM on attentional bias and diagnostic remission were observed (Linetzky et al., 2015; Price et al., 2016), others question the clinical utility of ABM and related cognitive training paradigms due to small effect sizes and high variability (Cristea et al., 2015). Until now, only one meta-analysis examined the effectiveness of ABM on social anxiety symptoms specifically (Heeren et al., 2015) and suggested that ABM has small effects on attentional bias and social anxiety symptoms. Together, these studies

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indicate that ABM's effects are small and inconsistent; suggesting there is room from improvement regarding the effectiveness of ABM targeting social anxiety.

To enhance the effectiveness of current ABM paradigms with the ultimate goal of improving its clinical utility, a crucial first step is to investigate whether certain factors moderate ABM's effects in an experimental study involving individuals with non-clinical levels of anxiety. Indeed meta-analyses have observed that ABM is particularly effective in reducing attentional bias and anxious symptomatology when delivered under certain conditions, highlighting the importance of identifying key moderating factors (Heeren et al., 2015; Jones & Sharpe, 2017; Linetzky et al., 2015; Price et al., 2016). Specifically, some meta-analyses have observed that lab-based ABM is more effective than remotely delivered (home-based) ABM in reducing social anxiety symptoms (Heeren et al., 2015; Linetzky et al., 2015; Price et al., 2016). Enhanced effects of ABM in the lab context may be explained by differences in the level of state anxiety experienced in the lab versus at home. When socially anxious participants perform ABM in the lab, state anxiety may be elevated by participants' need to interact with and worry about evaluation by a research assistant. In contrast, participants who perform ABM remotely do not have to interact with another person and so may experience lower levels of state anxiety during the training.

There are three potential reasons why elevated levels of state anxiety may enhance the effectiveness of ABM. First, theories on learning suggest that transfer of newly learned behavior to new situations might be improved when the context in which the behavior was learned matches the context in which the 'new' behavior needs to be applied (Bower, 1981; Morris et al., 1977; Tulving & Osler, 1968). Thus, to facilitate the transfer of ABM effects to the daily life, it may be necessary to incorporate anxiety-provoking stressors into ABM paradigms, so that the internal emotional context of the learning matches the internal context of the situation in which the trained bias is required to operate. Furthermore, theories postulate that an attentional bias in high socially anxious individuals is amplified in, or restricted to, situations in which state anxiety is elevated (Mathews & Mackintosh, 1998). Indeed, studies have shown that when high socially anxious individuals experience elevated levels of state anxiety, this amplifies their attentional bias for socially threatening information (e.g., Garner et al., 2006; Mansell et al., 1999). Additionally, from the perspective of Beck's diathesis-stress model, one can argue that it is beneficial to train in the context of social stressors as individuals with social anxiety might be especially prone to exhibit attentional biases (as a predisposition) in socially stressful situations. Hence, modifying attentional biases in a socially stressful situation may prevent further exacerbation of this anxiety-related cognitive vulnerability. Second, theories concerning exposure therapy suggest that in order to modify existing fear networks, the fear network needs to be activated during interventions (Foa & Kozak, 1986), suggesting that social stressors that activate relevant fear structures may enhance the efficacy of ABM. Third, learning theories propose that moderate levels of arousal are optimal for learning (Yerkes & Dodson, 1908). As ABM is often experienced as boring (e.g., Beard, Weisberg, & Primack, 2012), it may often be conducted in a state of low arousal, which might compromise learning. Thus, the effects of ABM may be improved by elevating arousal through inducing state anxiety levels during ABM.

Until now, only two studies have examined whether elevated levels of state anxiety or arousal enhanced the effectiveness of ABM targeting social anxiety. One of these studies found that ABM targeting individuals with social anxiety disorder was more effective in reducing social anxiety when state anxiety was induced before training compared to two control conditions (Kuckertz et al., 2014). Moreover, ABM following a state anxiety induction proved more effective in reducing attentional bias than the same ABM training conducted without a state anxiety induction (Kuckertz et al., 2014). However, this study did not check whether the fear induction successfully increased state anxiety. Another study investigated the role of elevating arousal on the effectiveness of ABM by randomizing participants with subclinical to clinical levels of social anxiety to either a social stress induction or control condition prior to a single session of ABM (Nuijs, Larsen, Bögels, Wiers, & Salemink, 2019). This study observed a trend effect suggesting that only when participants experienced relatively higher levels of subjective arousal ABM was more effective in reducing attentional bias than its control version. However, subjective arousal did not moderate training effects on attentional bias one day after training, stress reactivity, and post-event processing. It must be noted that in both studies state anxiety and arousal was only provoked before training and hence state anxiety may have dissipated during the training, resulting in limited effects. Thus, it is important to replicate these findings with a design that ensured that the state anxiety difference between conditions is sustained throughout the training. Another step to improve previous studies is to include various attentional bias assessment tasks that substantially differ from the task used in the ABM procedure itself (Hertel & Mathews, 2011; Mogg & Bradley, 2018). This will reveal whether the ABM procedures induce change in bias that transfer to assessment tasks, which are different from the paradigm used in training.

The current study is an experimental study designed to examine the fundamental research question whether manipulating state anxiety during ABM enhances its effectiveness in undergraduate students with moderate levels of social anxiety. As no experimental setup currently exists to examine this research question, the present study serves as a first step toward investigating the effect of elevated state anxiety during ABM, with the ultimate goal of establishing an experimental framework that can later be applied to individuals with clinical levels of social anxiety. We randomized participants to two versions of a dot-probe training: Attend-negative training in which the contingency was intended to train attention towards negative faces, and attend-positive training in which the contingency was intended to train attention towards happy faces. Prior and during training, participants received either a state anxiety induction condition or control condition. To examine whether elevated levels of state anxiety were maintained across training in the state anxiety induction condition, state anxiety was assessed throughout the training. Our first hypothesis was that the ABM would result in training induced differences in attentional bias consistent with the allocated training condition: Support for this will be obtained if participants who received the attend-positive training display less attentional bias to negative information post-training compared to participants who received the attend-negative training. Our second hypothesis was that the ABM induced differences in attentional bias between the training conditions would be larger for participants in the state anxiety induction condition than for participants in the control condition. The primary outcome for assessing effects on attentional bias was a dot-probe assessment task. Additionally, we examined whether ABM training effects generalized to a different type of assessment task, namely a visual search task.

2. Method

2.1. Design and ethics

Participants were randomized to one of 4 conditions, either a single session of attend-negative training or attend-positive training delivered in either a state anxiety induction or control condition. Attentional bias was assessed after the training by means of the dot-probe assessment task and a visual search assessment task (VSDT). Block randomization was performed on the following variables: Training condition, induction condition, and block order of the VSDT. The study was approved by the ethical committee of the Department of Psychology of the University of Amsterdam (2018-DP-9452) and by theUniversity of Western Australia Human Research Ethics Committee (RA/4/1/5243).

2.2. Participants

First year psychology students at the University of Western Australia

and University of Amsterdam were screened on social anxiety symptoms using the Social Interaction and Anxiety Scale (de Beurs et al., 2014; SIAS; Mattick & Clarke, 1998). A total of 788 students, who scored between the 30th to 80th percentile of the distribution of the screened sample ($SIAS_{total\ score}$ = 18–46), reflecting low to clinical levels of social anxiety, were invited to the study. Due to ethical considerations, we did not want to include students with very high levels of social anxiety (i.e., above the 80th percentile) as some participants would be randomized to the attend-negative training condition. Furthermore, we did not want to invite students with very low levels of social anxiety (i.e., below the 30th percentile) as they would probably not respond to the state anxiety manipulation. Other inclusion criteria were being a first-year student and an age below 31.[1] Of these 788 students, 165 students participated in the study of which five participants were excluded prior to data analyses because of incomplete data ($n = 2$) or technical errors during the experiment ($n = 3$). The final sample consisted of 160 participants (78.12% female; M_{age} = 19.44; SD = 1.88; range = 17–29) with an average SIAS score (the SIAS was assessed a second time during the experiment) of 26.67 (SD = 9.59; range = 7–49).

2.3. Materials

2.3.1. Questionnaires

The demographical questions included age, gender, and whether the language employed in the experiment (either English or Dutch) was the native language of the participants. Social anxiety was assessed with the SIAS (de Beurs et al., 2014; Mattick & Clarke, 1998). The SIAS consists of 20 items, which are rated on a 5-point Likert scale ranging from 0 (*not at all*) to 4 (*extremely*). Higher scores indicate higher levels of social anxiety. The reliability and validity of the SIAS are good (de Beurs et al., 2014; Mattick & Clarke, 1998). The internal consistency of the SIAS in this study was good (α = .73 at screening and α = .84 during the experiment).

State anxiety in response to the mood inductions was assessed with a Dutch version of the Spielberger State-Trait Anxiety Inventory-Short (STAI-short; Marteau & Bekker, 1992; Van Der Bij et al., 2003). The STAI-short consists of six items (calm, tense, upset, relaxed, content, and worried), which were presented in random order for each assessment. The items were rated on a visual analogue scale ranging from 1 (*not at all*) to 100 (*very much*) and the average of the six items was used as index of state anxiety. Higher scores indicated a higher level of state anxiety. The reliability and validity of the Dutch STAI-short are good (Van Der Bij et al., 2003). The internal consistencies of the STAI-short assessments in this study were good (all αs > .82).

2.3.2. Stimuli for the attentional bias assessment tasks and ABM training conditions

Faces displaying emotional expressions in the dot-probe training were drawn from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998). Specifically, we selected 32 face identities, 16 male and 16 female identities who were showing both a happy and angry expression, resulting in 64 face stimuli in the training set (identical to the set employed in Notebaert et al., 2018). To examine whether ABM effects generalized to a different set of faces, the stimuli for the attentional bias assessment tasks were selected from a different database, namely the Umea University Database of Facial Expressions (Samuelsson et al., 2012). Eight face identities were selected, 4 males and 4 females, who each displayed a happy and an angry expression, resulting in 16 face stimuli in the assessment set.

[1] The inclusion criterion of an age below 31 was not pre-registered. It was implemented during data collection as we wanted to keep the sample homogeneous in terms of age.

2.4. Attentional bias assessment tasks

2.4.1. Dot-probe assessment task

The effect of the ABM training on attentional bias to threat was assessed with a dot-probe assessment task (MacLeod et al., 1986). Each trial started with a fixation cross, which was appearing in the center of the computer screen for 500 ms. Then, two emotional expressions, a happy and angry expression, were presented simultaneously on the left and right side of the screen. A probe in the form of a faint grey line, oriented either horizontally or vertically, was then presented in the location of one of the former faces, and participants had to indicate as quickly as possible whether this line was horizontal by pressing the 'H' key on the keyboard, or vertical by pressing the 'V' key on the keyboard. The task consisted of 128 trials in total, probes appeared in the former location of the preceding angry faces on half of the trials and in the former location of the preceding happy faces in the other half of the trials. An attentional bias index was computed by subtracting the mean RT of trials in which the probe appeared in the locus of preceding angry faces from the mean RT of trials in which the probe appeared in the locus of the preceding happy faces. Positive scores indicated an attentional bias towards negative faces. The split-half reliability of the bias index was calculated via the mean Spearman-Brown adjusted Pearson correlation of 1000 permutated splits (stratified by trial type) (Parsons et al., 2019; Pronk et al., 2022) via the splithalfr R package (Pronk, 2020): r = .22, *95% CI* = [.06-.44]. Confidence intervals were estimated via a nonparametric bias-corrected and accelerated bootstrap (Efron, 1987; Efron & Narasimhan, 2020).

2.4.2. Visual search assessment task

To examine whether the effects of the ABM training transferred to a different type of bias assessment task, attentional bias was also assessed by means of the Emotional Visual Search Task (EVST; De Voogd et al., 2014). Each trial started with a fixation cross, on which participants needed to click. A 4x4 matrix of 16 faces was then presented until the participant selected one of the faces by a mouse click. Participants were asked to select either a single positive face in a matrix of negative faces (find-the-positive-face block; 36 trials) or to select the single negative face in a matrix of positive faces (find-the-negative- face block; 36 trials). Block order was counterbalanced over participants. Participants only received feedback in case of incorrect responses. An attentional bias index was computed by subtracting the mean RT on find-the-negative-face blocks from the mean RT on find-the-positive-face blocks. Larger positive scores indicated a greater attentional bias for negative faces. Using the same approach as for the dot-probe task, the split-half reliability estimate of the bias index of the visual search task was r = .80, *95% CI* = [.74-.85].

2.5. Attention bias modification training task

Participants were randomly assigned to either the attend-negative training or the attend -positive training (similar to the dot-probe training task in Notebaert et al., 2018). The objective of the ABM training was for participants to direct their attention towards the assigned training condition (i.e., so either towards happy or angry faces). The ABM training task was similar to the dot-probe assessment task, with the exception that, in the attend-positive training the probe consistently appeared in the locus of the preceding happy face on all trials, whereas in the attend-negative training the probe consistently appeared in the locus of the preceding angry face on all trials. The training task consisted of 4 blocks of 128 trials and was preceded by a practice block of 32 trials in which neutral face pairs were shown. Participants received feedback when they made incorrect probe discrimination responses.

2.6. State anxiety manipulation

Participants were randomly assigned to either the state anxiety induction condition or control condition. Prior to each ABM training block, participants received instructions for the corresponding condition. Based on the proposal that participants might experience slightly elevated levels of state anxiety due to the lab-context (e.g., Heeren et al., 2015), we decided to let participants in the control induction watch happy film fragments of Hollywood movies in order to minimize baseline state anxiety. To elevate state anxiety, participants in the state anxiety induction condition were subjected to a sham interview procedure, in which they were required to answer job interview questions in front of a video recorded selection committee. The state anxiety induction started with preparation time for the job interview: Participants were instructed to prepare for a job interview by taking the role of a job applicant seeking a job in the field of their current studies. They were given 3 min of preparation time for the interview. Then, the research assistant placed a laptop in front of the participants with a full screen recording webcam and started the first video fragment which displayed a selection committee of 2 males and 2 females. Prior to each training block, participants were prompted to call the research assistant who positioned the recording laptop in front of the participant and turned on the next video segment delivering the job interview questions. During the interview segments, the research assistant sat behind the participant, and gave the appearance of evaluating the performance of participants by means of an evaluation form, in order to elicit elevated anxiety by establishing a context of social evaluation. In the first anxiety induction video, the committee introduced themselves and instructed participants to answer each question within 2 min and to talk for the whole 2 min. Then, one of the committee members asked the first interview question. In the following video fragments, the committee asked different job interview questions. Examples of the job interview questions are: 'Why should we hire you and not others who applied for the same job?' or 'Which of your personal characteristics might make you less suitable for this job?'. The duration of the job interview fragments was matched to the happy film fragments and during the happy film fragments, there was no interaction between the participants and the research assistant.

2.7. Procedure

Students who met the inclusion criteria were invited by email to take part in the study. After participants signed the informed consent form, they were asked to sit behind the computer. The experiment started with demographical questions, SIAS and STAI-short (T1) followed by instructions and a practice block of a dot-probe task. Next, participants filled in the STAI-short (T2) followed by instructions for their induction condition (for the job interview or for the happy film fragments) after which they were asked to fill in another STAI-short (T3). Then, the first video fragment started followed by the STAI-short (T4), the first ABM training block, and another STAI-short (T5). This sequence was repeated four times, with each training block being preceded by a video fragment and a STAI measurement pre- and post-block. After the fourth training block, participants received the final video fragment followed by the STAI-short (T12). Then, attentional bias was assessed by means of the dot-probe assessment task followed by another STAI short (T13). After a dot-probe task, attentional bias was assessed by means of a visual search task, which was preceded by a practice block. Then, participants filled in several evaluation questions about the experiment. Participants who received the state anxiety manipulation were debriefed that it is normal to have a stressful reaction to this type of task and were given contact information for any further support if needed. The experiment took approximately 1,5 h to complete and participants received a financial reimbursement or course credit.

2.8. Power analysis

To the best of our knowledge, Kuckertz et al. (2014) is the only study so far which tested the moderating role of state anxiety on ABM training effectiveness. This study observed a medium effect size ($d = .50$) when performing a within-subject comparison of a pre vs. post-training measurement of attentional bias in the condition that received experimental ABM training preceded by a fear induction, ($t(38) = 3.15$, $p = .003$). The effect size was calculated based on the observed t-value and sample size of the corresponding training condition, $d = .50$ ($d = t/\sqrt{N}$; $3.15/\sqrt{39} = .50$). We conducted an a priori power analysis for performing a two-way interaction in an ANOVA by using G*Power 3.1 with an effect size of $f = .25$, power of .8, alpha of .05, 4 groups, 0 covariates, and a numerator df of 1. The required sample size is a minimum of 128 participants. To account for potential drop-out or a low accuracy rate, we aimed for a sample size of at least 160 participants.

3. Results

We pre-registered the analysis plan by using the AsPredicted.org template: https://osf.io/sk584/?view_only=675d5cdc65524836b81cdf3634c7166e.

3.1. Descriptive statistics

Australian, Dutch, and international students were equally distributed over the four training conditions, see Table 1 (for demographic characteristics of these samples, see Supplementary Material 1 [2]). There were no significant differences in age, SIAS total score, gender ratio, and native language ratio between the four training conditions, see Table 1.

3.2. Manipulation check state anxiety

In the state anxiety assessments eight multivariate outliers were identified using Mahalanobis Distance Test (Tabachnick & Fidell, 2012) and removed prior to the analyses (remaining $n = 152$). The sphericity-assumption was violated, $\chi^2(44) = 388.16$, $p < .001$, and hence we used the Greenhouse-Geisser correction for the degrees of freedom.

To examine whether the state anxiety condition was successful in elevating state anxiety compared to the control condition, a repeated measures ANOVA was performed with State Anxiety Condition (high vs. low) as the between-subjects factor and Time with baseline (T2[3]) vs. the 9 post-induction state anxiety assessments during and right after training (T3-T11, see Fig. 1) as the within-subjects factor. For the Time effect, we employed a simple contrast in which the baseline assessment was compared to the state anxiety assessments afterwards. Results revealed a significant main effect of Time, $F(5.55,832.43) = 7.45$, $p < .001$, partial $\eta^2 = .05$, which was subsumed by a significant interaction effect of State Anxiety Condition and Time, $F(5.55,832.43) = 29.52$, $p < .001$, partial $\eta^2 = .16$, see Fig. 1. This interaction was significant when each of the 9 post-induction assessments was compared to the baseline assessment, all p's $< .005$. As depicted by Fig. 1, participants who received the state anxiety induction demonstrated an increase in state

[2] As pre-registered [.], we tested whether the three student samples differed in terms of age, native language, gender, and SIAS total score, see Supplementary Material 1. As the samples differed on these characteristics, we added 'Type of sample' (Australian students, Dutch students, international students) as a main effect in the analyses. Since the main effect of 'Type of sample' was not significant in any of the analyses and more importantly did not change the conclusion based on the results, we removed this factor from the models.

[3] The second state anxiety (STAI-short) assessment (T2) was chosen as a baseline assessment as this assessment was closest to the first instruction for either the state anxiety induction or control condition.

Table 1
Demographic characteristics of the four training conditions.

	Attend-negative + HSA (*n* = 42)		Attend-negative + LSA (*n* = 38)		Attend-positive + HSA (*n* = 39)		Attend-positive + LSA (*n* = 41)		Between-group test
	M/n	*SD/%*	*M/n*	*SD/%*	*M/n*	*SD/%*	*M/n*	*SD/%*	
Age	19.14	1.72	19.32	1.42	19.41	1.89	19.88	2.34	$F(3,156) = 1.16$
SIAS[a]	27.38	10.78	26.74	8.69	25.38	9.60	27.12	9.30	$F(3,156) = .34$
Female	33	78.6	30	78.9	28	71.8	34	82.9	$\chi^2(3) = 1.49$
Native language	25	59.5	21	55.3	23	59.0	20	48.8	$\chi^2(3) = 1.22$
Type of sample									$\chi^2(6) = .88$
Australian	11	26.2	9	23.7	10	25.6	11	26.8	
Dutch	15	35.7	12	31.6	11	28.2	12	29.3	
International	16	38.1	17	44.7	18	46.2	18	43.9	
AB[a] indices									
Dot-probe task[b]	1.73	21.97	3.87	19.25	−4.28	22.26	−4.71	17.45	
Visual search task[b]	165.64	911.58	372.58	600.94	265.70	595.79	247.65	542.36	

Note. The variable 'native language' indicates for which percentage of the participants the language of the experiment (Dutch or English) was the same as their native language.
*$p < .05$, **$p < .01$, ***$p < .001$.
[a] SIAS = Social Interaction Anxiety Scale; AB = Attentional Bias.
[b] The sample of a dot-probe task was $n = 148$ and for the visual search task $n = 151$.

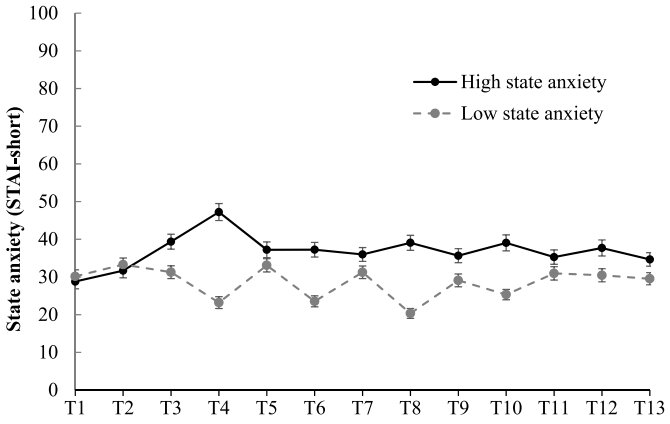

Fig. 1. Raw means of state anxiety levels at the baseline assessment and assessments after each assessment block and each induction video (with standard error bars). T1 = Baseline 1 (start experiment); T2 = Baseline 2 (pre-instruction induction); T3 = Post-instruction induction; T4 = Post-question 1; T5 = Post-training block 1; T6 = Post-question 2; T7 = Post-training block 2; T8 = Post-question 3; T9 = Post-training block 3; T10 = Post-question 4; T11 = Post-training block 4; T12 = Post-question 5 (prior to the dot-probe assessment task); T13 = Post-dot-probe assessment task (prior to the visual search assessment task).

anxiety between baseline and all following post-induction assessments, while participants who received the control condition did not. The between-group difference in state anxiety remained significant following completion of training trials, and was evident prior to the subsequent dot-probe assessment task, $t(150) = -2.64$, $p = .009$, and subsequent visual search assessment task,[4] $t(149) = -2.12$, $p = .035$.

3.3. Effect of state anxiety manipulation and ABM training on attentional bias post-training

3.3.1. Data reduction

Response latencies to calculate the bias indices were only used if participants made correct probe discriminations in a dot-probe task or selected the correct target in the EVST. As pre-registered, data of participants was only included in analyses if the overall accuracy percentage of the task was not below 85%. Outliers in response latencies were removed based on the median absolute deviation method (Leys et al., 2013). Response latencies were removed if they deviated more than 2.5 times the median absolute deviation from the participant's median response latency for that experimental condition (e.g., separately for the find-positive and find-negative block). After removal of these outlying response latencies, mean response latencies per participant per experimental condition were computed.

3.3.2. Dot-probe attentional bias assessment

Four participants were removed prior to the analyses because their overall accuracy fell below 85% on the dot-probe assessment task ($n = 148$). After removing these participants, the overall accuracy percentage on a dot-probe task was 94.74%. To investigate whether ABM training effects on attentional bias was larger when ABM training was performed in an elevated state of anxiety, we performed a 2 Training Condition (attend-negative vs. attend-positive) x 2 State Anxiety Condition (high vs. low) factorial ANOVA. In line with the expectations, results revealed a significant main effect of Training Condition, $F(1,144) = 4.77$, $p = .031$, $\eta^2 = .03$, reflecting a difference in bias scores in line with the allocated training conditions, with higher attentional bias scores for participants who had just completed the training in the attend-negative condition compared to the attend-positive condition (see Fig. 2). Contrary to our expectations, we did not observe a significant interaction effect of Training Condition and State Anxiety Condition, $F(1,144) = .15$, $p = .700$, partial $\eta^2 = .00$. Therefore, elevated levels of state anxiety did not increase the ABM induced difference in attentional bias, as assessed by a dot-probe task.

3.3.3. Visual search attentional bias assessment

One participant was removed prior to the analyses variable because this participant had a non-responsive mouse during the assessment ($n = 151$). The overall accuracy percentage on the EVST was 99.19%. To investigate whether ABM training effects on attentional bias were larger when ABM training was performed in an elevated state of anxiety, we performed a 2 Training Condition (attend-negative vs. attend-positive) x 2 State Anxiety Condition (high vs. low) factorial ANOVA. Contrary to our expectations, the results revealed no significant main effect of Training Condition, $F(1,147) = .01$, $p = .911$, $\eta^2 = .00$, or a significant interaction between Training Condition and State Anxiety Condition, $F(1,147) = 1.04$, $p = .310$, partial $\eta^2 = .01$. These results indicate that the observed ABM induced training differences on attentional bias as revealed by the dot-probe attentional bias assessment task did not

[4] For the comparison of the average state anxiety between the two state anxiety conditions prior to the visual search assessment, we included the same sample as for the analyses conducted with the visual search assessment as dependent variable ($n = 151$).

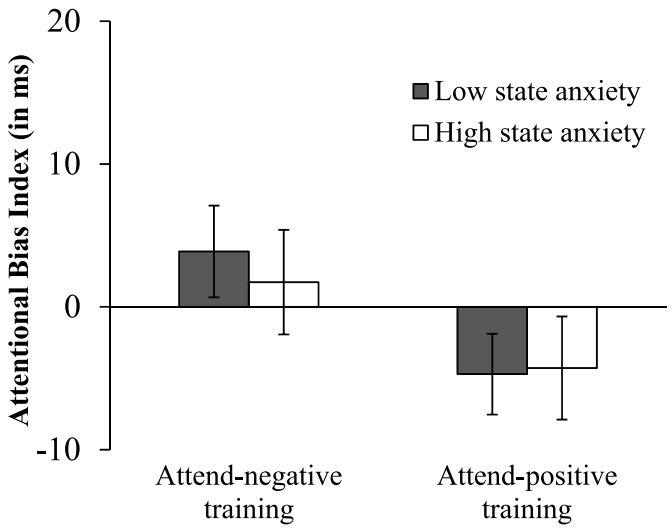

Fig. 2. Raw means of attentional bias index post-training as assessed with the dot-probe assessment task per condition (with standard errors bars).

transfer to the visual search attentional bias assessment task, either as main effect or in a manner that was moderated by the state anxiety manipulation.

4. Discussion

This study investigated the fundamental research question of whether elevated state anxiety during ABM enhanced its effectiveness in reducing attentional bias towards socially threatening information in undergraduate students with moderate levels of social anxiety. In line with our first hypothesis, we observed ABM induced differences between the training conditions, congruent with the allocated training condition, when assessing attentional bias post-training using the dot probe assessment task. However, contrary to our second hypothesis, this effect of ABM training on attentional bias was not moderated by state anxiety levels during training. The state anxiety manipulation was successful in inducing the intended differences in state anxiety, such that the state anxiety induction condition displayed higher levels of state anxiety during and after the ABM training compared to the control condition. Furthermore, although the ABM training induced the intended group difference on attentional bias measured using the dot-probe assessment task, this training effect did not transfer to the visual search assessment task. ABM training effects on attentional bias as assessed with the visual search task were also not moderated by state anxiety levels during training.

Contrary to our expectations based on cognitive theories on memory and learning (Bower, 1981; Tulving & Osler, 1968) and the preliminary results of Kuckertz et al. (2014), state anxiety did not moderate training effects on attentional bias as assessed with a dot-probe task or visual search task. Though direct comparisons with the two previous studies which induced state anxiety or arousal prior to ABM (Kuckertz et al., 2014; Nuijs, Larsen, Bögels, Wiers, & Salemink, 2019) are not possible because, unlike the current study, neither of these studies included a state anxiety manipulation prior to assessing bias. Furthermore, the two previous studies were testing a sample with subclinical and/or clinical levels of social anxiety (Kuckertz et al., 2014; Nuijs, Larsen, Bögels, Wiers, & Salemink, 2019). The findings of the current study indicate that in samples with low to subclinical levels of social anxiety, elevating state anxiety levels during training does not enhance the capacity of ABM training to modify attentional bias. However, based on the current study only, it is too early to refute the notion that state anxiety during ABM might be an effective strategy for improving ABM's effectiveness in samples with subclinical to clinical levels of social anxiety. Even more so since large effect sizes on attentional bias have been observed in samples with higher symptomatology (Beard et al., 2012) and hence, a moderating effect of state anxiety on ABM might be observed in a clinical sample. To test the moderating effect of state anxiety on the effects of ABM in a clinical sample, this would require a controlled design. Namely, unlike the design of the current study, a design in which an attend-positive training condition is compared to a no-contingency training condition and a state anxiety manipulation is compared to neutral mood condition. The results of the current study stand in contrast to the idea, based on theories on exposure therapy, that therapeutic change delivered with the aim of reducing anxiety-related symptoms will be optimized by activating the fear network during delivery of an intervention (Foa & Kozak, 1986). The lack of moderation of state anxiety on ABM effects is inconsistent with the suggestion that previous observed differences in the impact of ABM on attentional bias or anxious symptoms, when it delivered in home versus lab-context (Heeren et al., 2015; Linetzky et al., 2015; Mogoaşe et al., 2014), may be due to heightened state anxiety in the latter context. Of course, it will be prudent to base firm conclusions on subsequent replication of the present findings, but there is no evidence from this study that inducing state anxiety serves to increase the impact of this ABM procedure on attentional bias in individuals with moderate levels of social anxiety.

One potential explanation for the lack of moderation of state anxiety on ABM effects is that the manipulation method has not induced sufficiently intense or consistent elevations of state anxiety. Although state anxiety was significantly higher in the state anxiety induction condition than in the control condition throughout training, state anxiety levels nonetheless dropped across each ABM block, declining from completion of each interview question block to the end of each training block (see Fig. 1). This was illustrated by higher effect sizes of the state anxiety manipulation after the interview questions (d's = .52–1.46) compared to after the training blocks (d's = .22–.44). Hence, future studies should explore whether state anxiety manipulations that are more integrated into the ABM procedure enhance training effects (e.g., listening to negative cognitions during a training block). Furthermore, although we successfully elicited heightened state anxiety in the state anxiety induction compared to their baseline levels of state anxiety, the average level of state anxiety during training of this group was still quite modest, representing a score $M = 38.44$ on a 100 point scale ($SD = 15.13$). These modest levels of state anxiety in the state anxiety induction may be explained by our sample which had low to subclinical levels of social anxiety. Therefore, future studies should explore whether a more intense state anxiety elevation during training blocks may enhance the impact of the ABM procedure on attentional bias in samples with subclinical to clinical levels of social anxiety (e.g., imagining a social situation that is currently avoided).

Another possible explanation for the lack of moderation of state anxiety on ABM effects could be that state anxiety does not act as a moderating factor on its own but exerts influence on ABM training effects in interaction with other factors. This proposal is in line with recent models of anxiety which suggest that attentional biases are the result of an interplay of bottom-up processes and top-down cognitive control processes (Mogg & Bradley, 2018). For instance, momentary increases in state anxiety may have increased the salience of stimuli but only in individuals with certain levels of cognitive control. One candidate factor that could act as a moderator is attentional control, which is the extent to which one can regulate the allocation of attentional resources congruent with current goals (Eysenck et al., 2007; Shi et al., 2019). Pre-registered exploratory analyses on the interaction between state anxiety, ABM training condition, and a facet of attentional control (i.e., attentional focusing; see Derryberry & Reed, 2002) in a subset of the sample indeed revealed a pattern indicating that participants with high attentional focusing only picked up the training contingency when state anxiety was elevated and not when it was lower, while participants with low attentional focusing only picked up the training contingency when state anxiety was lower versus higher (see Supplementary Material 2).

One possible explanation could be that when individuals have low control, increases in state anxiety disrupt their ability to adhere to task requirements. In other words, the heightened salience of stimuli during heightened state anxiety could overshadow their ability to detect probes. Conversely, individuals with high control may find that elevated state anxiety motivates them to engage in learning the training contingency that might otherwise seem dull, thereby creating a "desirable difficulty" effect (Hertel & Mathews, 2011). Although these findings are of exploratory nature and need replication, these preliminary findings suggest that the interaction of attentional control and state variables during training should be further examined in future studies.

The finding that dot-probe based ABM manipulation served successfully to elicit a difference in attentional bias post-training is consistent with the previous finding that this dot-probe training is effective in inducing small differences ($\eta^2 = .03$) in attentional bias in individuals with moderate to heightened social anxiety (Heeren et al., 2015). Although the effects of training generalized to a different set of faces in the dot-probe attentional assessment task, they did not generalize to a different bias assessment task (i.e., visual search task; de Voogd et al., 2014). This might be explained by the fact that the VSDT measures a different facet of attention than a dot-probe task as the VSDT has explicit instructions with regard to the valence of the stimuli, stimulating goal-directed learning (Mogg & Bradley, 2018), whereas a dot-probe task has non-valence-related instructions. In line with this idea, the correlation between the two tasks was low, $r = .076$, $p = .336$. Furthermore, it must be noted that, although the current study and other studies found that the that the visual search task may yield a more psychometrically reliable measure of bias than a dot-probe task (Van Bockstaele et al., 2017), the validity of the task in detecting anxiety-linked bias in socially anxious samples may be limited as correlations between the visual search task and anxiety measures are often not significant (de Voogd et al., 2016; Klein, de Voogd, Wiers, & Salemink, 2018; Van Bockstaele et al., 2020). Of course, it remains unknown whether more extensive ABM training, perhaps spread across multiple sessions, would have resulted in more generalized changes in attentional bias. Despite the fact that other studies also observed that ABM training effects do not generalize beyond the training paradigm (de Voogd et al., 2016; Van Bockstaele et al., 2017), we expected that this generalization would have occurred if training effects of ABM would be enhanced through a state anxiety induction. It should be noted though that it is possible that the detected differences in attentional bias on the dot-probe task actually reflected differences in mood at the time of assessment. Therefore, future studies incorporating a state anxiety manipulation may need to include a neutralizing mood induction before bias assessment to ensure that all participants begin the assessment in a comparable mood state. In conclusion, future studies need to examine under which circumstances ABM is resulting in stable changes in attentional bias beyond its paradigm (Mogg & Bradley, 2018) and most importantly when these changes are accompanied by reductions in social anxiety.

This study has several strengths and limitations. An important strength is that this is one of the first studies to directly examine whether state anxiety levels during ABM influences its effectiveness in modifying an attentional bias towards socially threatening information. Furthermore, to the best of our knowledge, this is the first study that has continued the manipulation and assessment of state anxiety throughout the full ABM training session. Another strength is that we included a large sample of undergraduate students with moderate levels of social anxiety, which enabled us to detect medium sized effects. A limitation of this study is that we assessed state anxiety solely by self-reported measures. Given the possibility of demand effects, it would have been reassuring to verify the efficacy of this manipulation by also including more objective measures of arousal (e.g., Mauss et al., 2004). Furthermore, it must be noted that the reliability of the dot-probe assessment task was relatively low, which is a common challenge in the field of ABM (Vrijsen et al., 2024). This might also have impacted the power to detect ABM training effects and the moderating effect of state anxiety. While some investigators have pointed out that this can compromise the accurate classification of an individual's attentional style (Parsons et al., 2019), assessment tasks with lower levels of psychometric reliability can consistently reveal group differences in the processes they measure (De Schryver et al., 2016), which was the primary aim of this study. Furthermore, although employing bias indices facilitate comparisons between ABM studies, low reliability of bias tasks might be caused by the fact that bias indices are often based on difference scores (McNally, 2019). Hence, we suggest that future researchers should employ emerging approaches for assessing attentional selectivity that yield high psychometric reliability, such as, the dual-probe task (Grafton et al., 2021; MacLeod et al., 2019) or controlling for individual differences in the average response time (Kreuze et al., 2020). Additionally, given that the present study did not directly assess real-world transference but only task-transference, we want to acknowledge that future studies are needed to fully address the question of transference to real-world settings. Moreover, although we tried to recruit participants with a moderate level of social anxiety, the final range of SIAS scores was rather large. Hence, future studies should consider stratifying participants based on their social anxiety scores to mitigate the potential interference of variability in these scores on the detection of training effects. Furthermore, as pre-training attentional bias was not assessed, it is possible that participants had a low or no attentional bias prior to training and hence this might have limited the range to which state anxiety during ABM could improve training effects. Lastly, without a no-contingency ABM condition, neutral facial expressions in the assessment tasks, and a pre-assessment of attentional bias, it is difficult to disentangle whether the observed changes in attentional biases are attributable to each specific training condition itself and/or reflect pre-existing differences between participants. Hence, prior to drawing conclusions about the clinical utility of inducing state anxiety during ABM, future studies should include neutral facial expressions in the assessment tasks and a no-contingency ABM condition next to a attend-positive and attend-negative training.

To summarize, this study successfully manipulated state anxiety during ABM delivery to examine whether elevated levels of state anxiety would enhance the impact of an ABM procedure in modifying attentional bias towards socially threatening information. Although we observed ABM induced differences in attentional bias post-training as assessed with a dot-probe task, but not with a visual search task, the magnitude of this ABM training effect was not moderated by the level of state anxiety during training. Thus, the current study did not provide support for the view that inducing state anxiety would increase the impact of ABM on attentional bias in individuals with moderate levels of social anxiety. However, as this study addresses a fundamental research question, it is too early to draw firm conclusions about the role of state anxiety during ABM training in individuals with subclinical to clinical levels of social anxiety. However, the findings of this study may lead to future research on more applied questions regarding state anxiety during ABM training using a more controlled design.

CRediT authorship contribution statement

M.D. Nuijs: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **H. Larsen:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **B. Grafton:** Writing – review & editing, Supervision, Software, Methodology, Conceptualization. **C. MacLeod:** Writing – review & editing, Supervision, Methodology, Conceptualization. **S.M. Bögels:** Writing – review & editing, Supervision, Funding acquisition. **R.W. Wiers:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **E. Salemink:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2025.102030.

Data availability

The authors do not have permission to share data.

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