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Context matters: The role of subjective arousal during Attentional Bias Modification targeting socially anxious students

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ABSTRACT

Background and objectives: Attentional Bias Modification (ABM) paradigms targeting anxiety aim to reduce attentional biases for threatening stimuli and thereby reduce anxiety. Based on cognitive theories of performance and learning, elevated levels of arousal during ABM might enhance its effectiveness by making training more engaging and activating fear schemas. This study investigated whether elevated levels of arousal during ABM would increase its effectiveness in reducing attentional bias, stress reactivity, and post-event processing.

Method: We randomly assigned 79 high socially anxious students to a session of ABM or control training preceded by either a social stress or control induction to manipulate arousal. Training outcomes were attentional bias, stress reactivity, and post-event processing. Subjective arousal was assessed before, during, and after training.

Results: Results indicated that ABM was not successful in reducing attentional bias, stress reactivity or post-event processing, and that the effects of ABM were not moderated by subjective arousal. There was a trend towards ABM being more effective than control training in reducing attentional bias directly after training when participants were more aroused. However, this effect was not maintained one day after the training.

Limitations: The arousal manipulation did not result in significant between-group differences in subjective arousal.

Conclusions: This study did not provide support for the moderating role of arousal in ABM training effects. Replications with more effective mood induction procedures and more power are needed as a trend finding was observed suggesting that higher levels of arousal improved the direct ABM effects on attentional bias.

1. Introduction

Socially anxious individuals often have an attentional bias for socially threatening cues, such as facial expressions of disgust and anger (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenbrug, & Van Ijzendoorn, 2007; Mogg, Philippot, & Bradley, 2004). Cognitive models of anxiety suggest that this attentional bias plays a role in the aetiology and maintenance of social anxiety with attentional bias causally impacting anxiety (e.g., Bögels & Mansell, 2004; Morrison & Heimberg, 2013). To examine this causal relationship, Attention Bias Modification (ABM) paradigms targeting anxiety were developed as a procedure to change attentional bias and examine subsequent effects on anxiety (for a review, see MacLeod & Clarke, 2015). Thus far, studies that investigated the effectiveness of ABM targeting anxiety have observed mixed results (for reviews, see Jones & Sharpe, 2017; Mogg, Waters, & Bradley, 2017). While some meta-analyses are relatively positive about the training effects of ABM and report small to medium effects on attentional bias and anxious symptomatology (Hakamata et al., 2010; Heeren, Mogoaş;e, Philippot, & McNally, 2015), others are more sceptical (Cristea, Kok, & Cuijpers, 2015). In order to explain the discrepancy in findings, an important future avenue for ABM research is to investigate under which conditions ABM is most effective in eliciting bias change (Grafton et al., 2017).

One potentially important factor is the context during training. More specifically, several meta-analyses indicated that larger effect sizes on symptom reduction were found in lab-based ABM versus home training or internet-based ABM training (e.g., Heeren, Mogoaşe, Philippot, & McNally, 2015; Mogoaşe et al., 2014). Larger effect sizes in

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the lab can possibly be explained by the fact that the lab environment is more controlled compared to the home environment, where more distracting factors are present and the environment is more variable. Another possible explanation for the increased effectiveness of lab-based training is that the lab provides the right context to modify biases. The lab might provoke anxious feelings due to interactions with unfamiliar persons, which is especially anxiety provoking for socially anxious individuals who often fear negative evaluations of others. This activation of fear schemas potentially increases the effects of ABM as some studies suggest that the attentional bias is more pronounced under higher levels of state anxiety (e.g., Garner, Mogg, & Bradley, 2006; Mansell, Clark, Ehlers, & Chen, 1999; Mogg, Bradley, De Bono, & Painter, 1997). Furthermore, research on exposure therapy suggests that in order to reduce fear and anxiety, activation of the fear structure by being exposed to elements of the fear structure is needed (Foa & Kozak, 1986).

From the perspective of cognitive theories on performance and learning, increased levels of social anxiety, likely accompanied by increased arousal, during ABM can indeed be beneficial for its effectiveness. One reason why arousal may influence ABM effectiveness, is that cognitive theories predict that moderate levels of arousal (vs. high or low levels) are most optimal for performance (Yerkes & Dodson, 1908). As ABM is often perceived as boring (Beard, Weisberg, & Primack, 2012), which is most likely accompanied by low levels of arousal, increased arousal might improve learning during ABM. Furthermore, cognitive theories on memory and learning suggest that recall of new behaviour is increased when behaviour is learned in the same context as the context in which the newly acquired behaviour needs to be applied, also referred to as encoding specificity or mood-dependent memory (Bower, 1981; Tulving & Osler, 1968). As socially anxious individuals may only have an attentional bias, or may be particularly hampered by their attentional bias in situations which provoke higher levels of social anxiety, performing ABM while being in a state of heightened social anxiety and arousal might increase the transfer of ABM effects to daily life. One preliminary study of Kuckertz et al. (2014) supported this hypothesis and observed that ABM was more effective than two control conditions in reducing social anxiety when it was preceded by a self-initiated fear induction (e.g., making a phone call). As the study of Kuckertz et al. (2014) did not assess whether arousal or state anxiety levels changed after the anxiety induction, it remains unclear whether elevated levels of arousal and state anxiety increased ABM effects. Therefore, we assessed subjective arousal at multiple times during the experiment in order to investigate whether arousal levels before and during training might influence training effectiveness.

The aim of this study was to investigate whether training effects of ABM would be larger when the training is performed under elevated levels of arousal versus relatively lower levels of arousal. Specifically, students with subclinical to clinical levels of social anxiety were randomized to one session of experimental ABM (find-the-positive-face condition; de Voogd, Wiers, Prins, & Salemink, 2014) or a control version (find-the-flower condition; Dandeneau, Baldwin, Baccus, Sakellaropoulo, & Pruessner, 2007) preceded by either a social stress induction (anticipation of a speech) or control induction (no anticipation). Visual search ABM was chosen as the training paradigm since the explicit instructions in this training with regard to the valence of the stimuli (i.e., 'find the positive face') may facilitate goal-directed processing, as opposed to other ABM paradigms with non-valence-related training instructions (Mogg & Bradley, 2018). Training outcomes were attentional bias, stress reactivity in response to a speech task, and post-event-processing the day after the speech task, which is an important maintaining factor of social anxiety (e.g., Abbott & Rapee, 2004; for a review, see; Brozovich & Heimberg, 2011). We hypothesized that the level of subjective arousal would moderate ABM's training effects. Namely, we expected that elevated levels of subjective arousal will enhance ABM effects compared to relatively lower levels of arousal.

2. Method

2.1. Design and ethics

Participants were randomly allocated over 4 conditions; either visual search ABM training or control training preceded by either a social stress induction or control induction (day 1). Attentional bias was assessed[1] before training (day 1) and twice after training, directly after training (day 1) and the following day (day 2). Stress reactivity was assessed by means of a speech task on the day after the training (day 2) followed by an assessment of post-event processing the day after the speech task (day 3). The study was approved by the Ethical Review Board of the University of Amsterdam (2016-DP-6655).

2.2. Participants

Participants were recruited via online and flyer advertisements distributed at the University of Amsterdam. The screening procedure consisted of the Social Phobia and Anxiety Inventory (SPAI-18; de Vente, Majdandzic, Voncken, Beidel, & Bögels, 2014), which was mixed with filler items (in order to obscure the goal of the screening), questions about visual acuity, and demographical questions. The inclusion criterion was SPAI-18 scores of 28 or higher, since we wanted to select a subclinical to clinical sample, and was based on the mean ($M = 27.8$) of a healthy sample in a validation study (de Vente et al., 2014). The SPAI-18 was chosen as a screening questionnaire since it has a good screening capacity (de Vente et al., 2014), with a clinical cut-off score of 36 and higher for non-clinical samples and a cut-off score of 46 and higher for clinical samples. Additional inclusion criteria were being aged between 18 and 32, and having no problems with visual acuity. Participants received either course credits or a financial reimbursement of 15 euro. A total of 83 undergraduate students participated in the study of which 4 were excluded based on their age (> 32). The final sample consisted of 79 participants (Mage = 21.92, $SD = 2.55$; 75.9% female), of which one participant had missing data for the bias assessment of session 2 due to a technical error, one participant dropped out after the first session, and three participants dropped out during the stress reactivity task. The final sample had an average SPAI-18 score of 62.79 ($SD = 12.14$; range = 38.45–93.15) indicating that the sample had subclinical to clinical levels of social anxiety (de Vente et al., 2014).

2.3. Materials

2.3.1. Questionnaires

2.3.1.1. Social anxiety (day 1). Social anxiety was assessed with the brief version of the Social Phobia and Anxiety Inventory (SPAI-18; de Vente et al., 2014). The total score ranged between 0 and 108, with higher scores reflecting more social anxiety. Internal consistency in this sample was excellent ($\alpha = 0.92$).

2.3.1.2. Fear of public speaking (day 1). Fear of public speaking was assessed with the Dutch version of the Personal Report of Confidence as a Speaker Self-Report Questionnaire-Modified (PRCS-M; Gallego, Emmelkamp, van der Kooij, & Mees, 2011). The total score ranged between 30 and 180, with higher scores reflecting more fear of public speaking. Internal consistency in this sample was excellent ($\alpha = 0.95$).

2.3.1.3. Post-event processing (day 3). Post-event processing was assessed with the extended version of the Post-Event Processing Questionnaire (E-PEQ; Fehm, Hoyer, Schneider, Lindemann, & Klusmann, 2008) and assesses the extent to which someone negatively reviews a past social-evaluative situation. Items were rated

[1] Eye-tracking data was also collected during both attentional bias assessments but this data was not included in the current manuscript.

on a visual analogue scale from 0 to 100, resulting in a total score ranging between 0 and 1700, with higher scores reflecting more post-event processing. Internal consistency in this sample was excellent ($\alpha = 0.94$).

2.3.1.4. Subjective arousal (day 1 and 2). Subjective arousal was assessed with the Physical Arousal Questionnaire (PAQ; Dieleman, van der Ende, Verhulst, & Huizink, 2010; Kallen, 2002). The original version was adapted by adding two extra items: 'Are you blushing?' and 'Do you consider withdrawing from the experiment?' as blushing and avoidance are considered to be important symptoms of social anxiety (Bögels, Rijsemus, & De Jong, 2002; Heeren & McNally, 2016). Based on reliability analysis, the item on avoidance was removed as it decreased the reliability on most assessments, resulting in an 8-item PAQ with a total score ranging between 8 and 72. Higher scores on the PAQ, reflected a higher level of subjective arousal. Internal consistency in this sample was good ($\alpha = 0.79–0.86$).

2.3.2. Task stimuli

The face stimuli for the attentional bias assessment and visual search ABM were drawn from the Umeå University Database (Samuelsson, Jarnvik, Henningsson, Andersson, & Carlbring, 2012). Faces were selected based on their validity ratings (for details, see Samuelsson et al., 2012) and an age range of 17–32 years. Angry, disgust, and fearful emotional expressions were selected. Angry and disgusted faces were selected since previous studies suggested socially anxious individuals have an attentional bias for these expressions (e.g., Amir et al., 2005; Mogg et al., 2004). Fearful faces were selected as preliminary findings suggested that socially anxious individuals have an enhanced response to fearful faces compared to neutral or happy faces (Killgore & Yurgelun-Todd, 2005; Phan, Fitzgerald, Nathan, & Tancer, 2006).

In order to test whether training effects would generalize to different faces, two face sets were created of which one was presented during the pre-assessment and training and the second one during the two post-assessments. The allocation of the two face sets to either the pre-assessment and training or to the two post-assessments was counterbalanced across participants. The two face sets consisted of 18 happy faces and 6 faces of each negative emotion, resulting in 36 faces per set (50% female; similar to de Voogd et al., 2014). For the practice trials of the assessment and training, separate face sets were created.

2.3.3. Attentional bias assessment task (day 1 and 2)

Attentional bias was assessed with the Emotional Visual Search Task (EVST) as described in 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 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. The assessment was preceded by 3 find-the-positive-face and 3 find-the-negative-face practice trials. An attentional bias index was computed by subtracting the mean RT of find-the-negative-face blocks from the mean RT of find-the-positive-face blocks (de Voogd et al., 2014; 2016). Positive scores indicated an attentional bias for negative faces.

Bootstrapped split-half reliability estimates were obtained for all bias assessments by using the *splithalf* package (Parsons, 2018) in R (R Core Team, 2018), which performed 5000 random splits (Parsons, Kruijt, & Fox, 2019). Reliability estimates were $r = 0.64$, *95% CI* = [0.52-0.73] (Spearman-Brown corrected $r_{sb} = 0.78$, 95% CI [0.69-0.85]) at the pre-assessment, $r = 0.54$, *95% CI* = [0.41-0.66] ($r_{sb} = 0.70$, 95% CI [0.58-0.80]) at the first post-assessment, and $r = 0.41$, *95% CI* = [0.27-0.55] ($r_{sb} = 0.58$, 95% CI [0.42-0.71]) at the second post-assessment.

2.3.4. Attention Bias Modification training and control training task (day 1)

The visual search ABM training was the same as the find-the-positive-face block of the EVST (de Voogd et al., 2014). The training consisted of 4 blocks of 36 trials and was preceded by 6 practice trials (3 find-the-positive-face and 3 find-the-negative-face). The control training was the find-the-flower training of Dandeneau et al. (2007) in which participants had to select the 5-petaled flower as fast as possible in a matrix of 7-petaled flowers. This training was preceded by 3 practice trials. In other aspects, the control training was similar to the visual search training.

2.3.5. Social stress and control induction (day 1)

In order to manipulate arousal, participants were randomized over a social stress induction or control induction condition. The induction started after administration of the questionnaires. All participants received instructions about a presentation-related task that they needed to complete after the training. This could either be giving a 5-min speech in front of a job interview committee while being videotaped and compared to the performance of other participants (speech task) or evaluating a recorded presentation of another student (evaluation task). To determine their task, participants could pick an envelope from a stack of envelopes. Participants in the social stress induction were told that they could pick an envelope after the training with the goal to induce anticipatory fear by introducing the chance of having to give a speech. Participants in the control condition were allowed to pick an envelope immediately after the instruction with the goal to remove any potential fear of having to give a speech before the start of the training. All envelopes contained the evaluation task and hence at the end of the experiment, all participants evaluated a recorded presentation of a student to make the envelope procedure believable.

2.3.6. Stress reactivity task (day 2)

The stress reactivity task was similar to the presentation component of the Trier Social Stress Task (Kirschbaum, Pirke, & Hellhammer, 1993), which has been shown to successfully induce stress in individuals with social anxiety symptoms (e.g., Krämer et al., 2012; van Veen et al., 2009). Participants were asked to convince a job committee in a 5-min presentation that they were the best candidate and to describe their positive and negative characteristics. Participants received 3 min of preparation time and could write down notes but were not allowed to use their notes during the presentation. Participants were videotaped and told that their performance would be compared to that of other participants afterwards. The stress reactivity task was administered the day after the ABM session since experimental studies on memory suggest that the consolidation of emotional memory, as was the case for the social stress induction, is enhanced after sleep (e.g., Wagner, Gais, & Born, 2001).

2.4. Procedure

Participants were invited to take part in a study 'to improve presentation skills' in order to obscure the aims of the study. After participants completed the screening procedure, they were invited for two sessions on two consecutive days, referred to as day 1 and 2 (see Fig. 1 for an overview of the design). On day 1, participants were informed about the procedure of the experiment, which stated that at the end of both test sessions they will receive a task which involves presenting, and signed the informed consent. The experiment started with several questionnaires followed by instructions for the induction condition. Next, participants performed the pre-training attentional bias assessment, their respective training condition, and the first post-training attentional bias assessment. Half-way during training, participants received a reminder about their respective induction condition (i.e., a reminder about the speech task in the social stress induction or evaluation task in the control induction). At the end of the session of day 1,

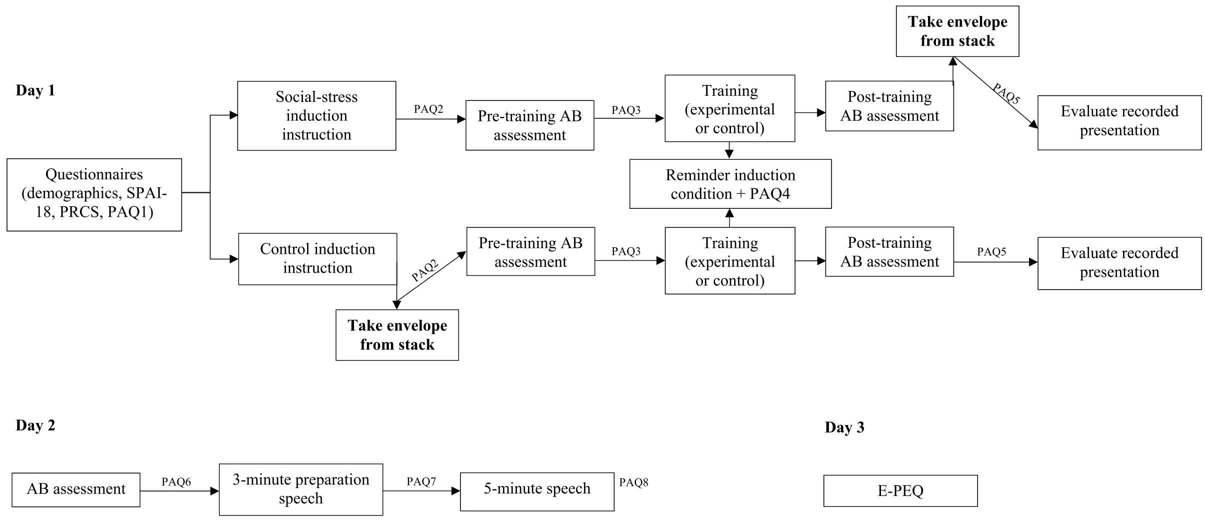

Fig. 1. Overview of the experimental design.

all participants evaluated a recorded presentation. The session on day 2 started with the second post-training attentional bias assessment. Next, participants received 3 min to prepare for the stress reactivity task after which the committee members entered the room, turned on the camera, and asked the participant to start the presentation. On day 3, participants were requested to fill out the E-PEQ online. Subjective arousal was assessed multiple times during the sessions on day 1 and 2 (see Fig. 1).

2.5. Analyses

To examine the effects of ABM condition and arousal on the outcome measures, hierarchical regression analyses were performed. All continuous predictors in the model were centred. In each model, the following covariates were entered in the first step: Block order of the EVST, face set order of the EVST, and pre-training social anxiety (SPAI-18 total score). Covariates were removed from the model if $p > .1$. In the second step of the model, ABM condition and arousal were entered and their interaction term was entered in the third step. Effects with $p < .05$ were defined as significant whereas effects with $p < .1$ were defined as a trend effect.

3. Results

3.1. Descriptive analyses

There were no significant baseline differences between the ABM conditions (Table 1) or Induction conditions regarding attentional bias, social anxiety, or demographic characteristics. At baseline, there was a significant attentional bias for negative information, $t(78) = 8.63$, $p < .001$. Social anxiety did not correlate with any of the attentional bias assessments (all *ps* $> .346$).

3.2. Manipulation check social stress induction

In order to test whether the social stress induction was successful in increasing subjective arousal, we performed a repeated-measures ANOVA with Induction (Social stress vs. Control induction) as between-subjects factor and Time (Pre-induction vs. Post-induction; PAQ1 vs. PAQ2 on day 1 in Fig. 1) as within-subjects factor. There was no significant interaction between Time and Induction condition, $F(1,77) = 0.01$, $p = .915$, suggesting that the social stress induction did not result in a larger increase in arousal compared to the control induction. Additionally, we tested whether the average arousal before

Table 1
Means and standard deviations of the group characteristics per training condition.

	ABM $n = 43$	ABM control $n = 36$
Age (*SD*)	22.02 (2.63)	21.81 (2.48)
Female (%)	34 (79.10)	26 (72.20)
Dutch nationality (%)	35 (81.40)	31 (86.10)
Social anxiety (*SD*)	60.96 (12.42)	64.98 (11.58)
Fear of public speaking (*SD*)	101.95 (23.75)	110.08 (27.94)
Attentional bias (*SD*)		
Pre-training (day 1)	850.71 (1004.51)	842.60 (696.37)
Post-training (day 1)	626.32 (790.75)	922.89 (735.13)[a]
Post-training (day 2)	675.18 (628.61)	715.85 (517.83)
Subjective arousal (*SD*)		
Pre-induction (PAQ1 – day 1)	18.26 (1.35)	19.56 (1.75)
Post-induction (PAQ2 – day 1)	16.40 (0.96)	19.11 (1.51)
Pre-training (PAQ3 – day 1)	15.07 (0.84)	15.61 (1.33)
Mid-training (PAQ4 – day 1)	13.69 (0.77)	14.69 (1.06)
Post-training (PAQ5 – day 1)	12.74 (0.72)	12.67 (0.92)
Baseline pre-speech (PAQ6 – day 2)	14.51 (7.94)	12.46 (3.44)
Post-preparation speech (PAQ7 – day 2)	22.12 (9.89)	19.86 (7.03)
Post-speech (PAQ8 – day 2)	26.33 (12.41)	25.12 (10.72)
Post-event processing on day 3 (*SD*)	529.95 (368.24)	532.59 (327.75)

[a] One participant of the post-training bias assessment was regarded as missing due misunderstanding of the task instructions (n = 35).

training (PAQ2 and PAQ3 on day 1) and during training (PAQ4 on day 1) was significantly higher in the social stress induction than the control induction condition. An independent *t*-test revealed that the social stress induction condition did not have higher average arousal than the control induction condition, $t(77) = 0.49$, $p = .627$. Given that the manipulation was unsuccessful in creating two groups, the average score of arousal was now entered as a continuous predictor in the following analyses to evaluate its effect on ABM. As participants received different instructions depending on the induction condition, induction condition was entered as a covariate in the analyses (control induction as reference category).

3.3. Attentional bias

3.3.1. Data reduction

Incorrect trials (0.04% for all assessments), trials with RTs < 200 ms, and trials with RTs higher than 2 *SDs* of the participant's mean RT for the corresponding block were removed. After removing these trials, the mean RT for the find-the-positive-face block

Table 2
Final regression models of the outcome attentional bias at the first and second post-assessment.

	First Post-Assessment (day 1)				Second Post-Assessment (day 2)			
Predictors	*B*	*SE B*	*ß*	*95% CI for B*	*B*	*SE B*	*ß*	*95% CI for B*
Step 1								
Block order EVST	327.00	169.48	.21†	−10.63, 664.62	307.93	124.99	.27*	58.87, 556.98
Pre-training bias	0.20	0.10	.22*	0.00, 0.39	0.15	0.07	.23*	0.01, 0.29
Step 2								
Block order EVST	338.66	167.33	.22*	5.17, 672.14	293.21	126.35	.25*	41.32, 545.09
Pre-training bias	0.18	0.10	.21†	−0.01, 0.37	0.16	0.07	.25*	0.02, 0.30
ABM condition	−272.89	166.88	-.18	−605.49, 59.71	−38.04	125.61	-.03	−288.44, 212.36
Average subjective arousal	16.13	12.26	.14	−8.30, 40.56	−10.14	9.20	-.12	−28.48, 8.21
Step 3								
Block order EVST	359.87	165.13	.23*	30.68, 689.05	295.45	127.75	.26*	40.71, 550.18
Pre-training bias	0.20	0.10	.23*	0.01, 0.39	0.16	0.07	.25*	0.02, 0.31
ABM condition	−269.57	164.30	-.17	−597.08, 57.95	−37.73	126.47	-.03	−289.91, 214.45
Average subjective arousal	39.10	17.44	.35*	4.33, 73.86	−8.31	13.36	-.10	−34.95, 18.34
ABM x Average subjective arousal	−44.00	24.12	-.28†	−92.09, 4.09	−3.52	18.54	-.03	−40.48, 33.44

Note. Average subjective arousal refers to the average of PAQ2, PAQ3, and PAQ4 on day 1. First post-assessment: Step 2: $R^2 = 0.158$ and $\Delta R^2 = 0.054$ ($p = .102$); Step 3: $\Delta R^2 = 0.037$ ($p = .072$); $n = 78$; Second post-assessment:
Step 2: $R^2 = 0.151$ and $\Delta R^2 = 0.015$ ($p = .535$); Step 3: $\Delta R^2 = 0.000$ ($p = .850$); $n = 77$. EVST = Emotional Visual Search Task; ABM = Attentional Bias Modification.
†$p < .10$, *$p < .05$, **$p < .01$, ***, $p < .001$.

and find-the-negative-face block were computed per participant and the attentional bias index was computed. Data of one participant was regarded as missing for post-assessment 1 as the participant misunderstood the task instructions during that assessment. All participants had an accuracy rate of > 96% for all the assessments.

3.3.2. Attentional bias changes

Results revealed that ABM condition was not a significant predictor of attentional bias at the first and second post-assessment (Table 2). We did observe a trend ($p = .072$; $f^2 = 0.05$) towards an interaction between ABM condition and subjective arousal in predicting attentional bias at the first post-assessment. Follow-up simple slope analyses revealed that, in line with our hypothesis, experimental ABM was more effective in reducing attentional bias than ABM control when participants were relatively highly aroused (> 1 *SD*), $ß_{ABM\ condition} = -0.37$, $p = .016$, but not when they were not aroused (< 1 *SD*), $ß_{ABM\ condition} = 0.02$, $p = .887$ (Fig. 2). Contrary to our expectations, attentional bias at the second post-assessment was not significantly predicted by the interaction of ABM condition and subjective arousal. There was a main effect of block order of the EVST indicating post-training attentional bias was higher when the find-the-negative block was followed by the find-the-positive block compared to when the find-the-positive block was followed by the find-the-negative block. However, block order did not interact with ABM condition and arousal in predicting attentional bias at the first or second post-assessment (all p's > 0.336).

3.4. Stress reactivity to a public speech task

To investigate whether ABM condition and subjective arousal during training interacted in predicting arousal increases in response to a stress-reactivity task, we performed two regression analyses with subjective arousal after the speech preparation (i.e., PAQ7 on day 2 in Fig. 1) and after completion of the speech (i.e., PAQ8 on day 2) as outcomes in separate models. Results revealed that ABM condition did

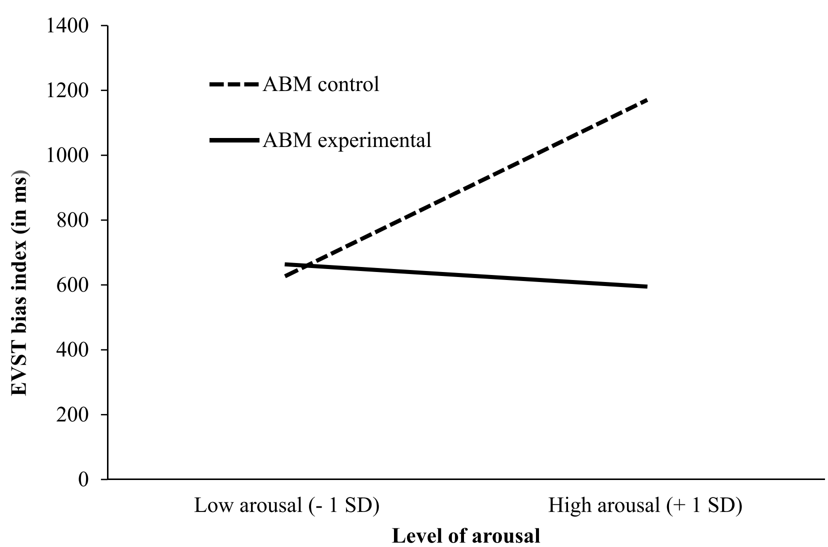

Fig. 2. The interaction between ABM condition and the average level of subjective arousal, which is a continuous moderator depicted here from - 1 SD to +1 SD, in predicting attentional bias (higher index indicates stronger bias) at the first post-assessment.

Table 3
Final regression models of the outcome stress reactivity.

Predictors	Post-Preparation Speech Arousal (PAQ2 – day 2)				Post-Speech Arousal (PAQ8 – day 2)			
	B	SE B	ß	95% CI for B	B	SE B	ß	95% CI for B
Step 1								
Baseline pre-speech arousal (day 2)	0.90	0.11	.66***	0.68, 1.11	0.67	0.17	.37***	0.32, 1.02
Induction	−3.52	1.37	-.20*	−6.25, 0.79	−4.97	2.23	-.22*	−9.42, −0.52
SPAI-18	0.17	0.06	.23**	0.05, 0.28	0.37	0.09	.38***	0.18, 0.55
Step 2								
Baseline pre-speech arousal (day 2)	0.69	0.13	.51***	0.44, 0.95	0.19	0.21	.11	−0.23, 0.61
Induction	−3.88	1.34	-.22**	−6.55, −1.20	−5.91	2.13	-.26**	−10.15, −1.66
SPAI-18	0.11	0.06	.15†	−0.02, 0.23	0.24	0.10	.25*	0.04, 0.43
ABM condition	2.14	1.38	.12	−0.61, 4.89	2.59	2.17	.11	−1.73, 6.91
Average subjective arousal	0.33	0.13	.26*	0.07, 0.59	0.80	0.23	.44**	0.34, 1.27
Step 3								
Baseline pre-speech arousal (day 2)	0.71	0.14	.52***	0.43, 0.99	0.19	0.22	.10	−0.26, 0.63
Induction	−3.87	1.35	-.22**	−6.56, −1.18	−5.90	2.14	-.26**	−10.18, −1.62
SPAI-18	0.11	0.06	.15†	−0.02, 0.24	0.24	0.10	.25*	0.04, 0.44
ABM condition	2.10	1.40	.12	−0.69, 4.89	2.60	2.19	.11	−1.76, 6.96
Average subjective arousal	0.35	0.15	.28*	0.04, 0.66	0.79	0.30	.43*	0.18, 1.40
ABM x Average subjective arousal	−0.06	0.21	-.03	−0.48, 0.36	0.03	0.36	.01	−0.70, 0.75

Note. Average subjective arousal refers to the average of PAQ2, PAQ3, and PAQ4 on day 1. Post-Preparation Speech Arousal: Step 2: R^2 = 0.597 and ΔR^2 = 0.045 (p = .022); Step 3: ΔR^2 = 0.000 (p = .789); n = 78; Post-Speech Arousal: Step 2: R^2 = 0.441 and ΔR^2 = 0.100 (p = .003); Step 3: ΔR^2 = 0.000 (p = .946); n = 77. SPAI-18 = Social Phobia and Anxiety Inventory-18; ABM = Attentional Bias Modification.
†p < .10, *p < .05, **p < .01, ***, p < .001.

not significantly predict subjective arousal after the speech preparation or subjective arousal after the speech (Table 3). Results revealed that ABM condition and the subjective arousal during training did not interact in predicting arousal levels after the speech preparation or after the speech (Table 3).

3.5. Post-event processing

To investigate whether the effect of ABM on post-event processing at day 3 would be moderated by the subjective arousal during the training, we performed a regression analysis with post-event processing as an outcome. Results revealed that ABM condition by itself or in interaction with subjective arousal did not predict increases in post-event processing on day 3, the day after the speech task (Table 4).

3.6. Power analysis

As the original design (ABM condition x Induction) was changed due to the failed arousal manipulation, a post-hoc sensitivity power analysis was performed in G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). In order to test whether this study was able to detect an interaction effect between ABM condition and the continuous measure of subjective arousal, we conducted a power analysis (power = 0.80; alpha = .05) for detecting a significant R^2 increase in multiple regression models (Step 3 in each regression model). Given the sample size (n = 77–78), the number of tested (1) and total predictors (4–6), the f^2 was approximately 0.10 and hence we were able to detect the expected medium effect size (based on Kuckertz et al., 2014), but not a small effect size.

Table 4
Final regression model of the outcome post-event processing.

Predictors	Post-Event Processing			
	B	*SE B*	*ß*	*95% CI for B*
Step 1				
SPAI-18	11.92	2.99	.42***	5.97, 17.87
Step 2				
SPAI-18	10.61	3.44	.37**	3.76, 17.46
ABM condition	44.50	74.41	.06	−103.79, 192.79
Average subjective arousal	6.01	6.04	.12	−6.01, 18.04
Step 3				
SPAI-18	10.87	3.46	.38**	3.98, 17.76
ABM condition	44.45	74.53	.06	−104.13, 193.03
Average subjective arousal	0.87	8.48	.02	−16.04, 17.77
ABM x Average subjective arousal	9.30	10.75	.13	−12.12, 30.73

Note. Average subjective arousal refers to the average of PAQ2, PAQ3, and PAQ4 on day 1. Step 2: R^2 = 0.190 and ΔR^2 = 0.015 (p = .512); Step 3: R^2 = 0.199 and ΔR^2 = 0.008 (p = .390); n = 77. SPAI-18 = Social Phobia and Anxiety Inventory-18; ABM = Attentional Bias Modification.
†p < .10, *p < .05, **p < .01, ***, p < .001.

4. Discussion

This study aimed to examine whether elevated levels of subjective arousal could enhance the effects of a single session of ABM in reducing attentional bias, stress reactivity, and post-event processing in socially anxious students. As the social stress induction was not successful in increasing subjective arousal, the average subjective arousal before and during the training session was investigated as a moderator of ABM effectiveness. Results revealed a trend towards subjective arousal moderating ABM effects on attentional bias at the first post-training assessment. As hypothesized, we observed that when arousal levels were elevated, experimental ABM was more effective than its control version in reducing attentional bias. When arousal levels were low, there was no difference in attentional bias between the two ABM conditions. Consistent with Kuckertz et al. (2014), this suggests that emotional arousal before and during training may play a role in ABM's effectiveness. Furthermore, these findings potentially illustrate the importance of activating fear-related schemas during training (see Foa & Kozak, 1986). Namely, although the social stress induction was not successful, the lab context in itself might have induced elevated levels of arousal in some participants by activating fear-related schemas of similar social situations. Clearly, these findings need replication and should be interpreted with caution since the moderating effect of arousal on ABM was not significant.

Note that subjective arousal did not moderate the training effects on bias at the second post-training assessment or stress reactivity and post-event processing. Explanations for the null findings might be that the average arousal levels during training were too low ($M_{average\ arousal}$ = 16.06) or that the variance was too little ($SD_{average\ arousal}$ = 6.85). Based on the preliminary results of Kuckertz et al. (2014; d = 0.50 for the ABM + fear induction condition), a medium effect size for the interaction of ABM condition and arousal could be expected and detected with the current sample. However, as the interaction effect of ABM condition and subjective arousal in predicting bias at the first post-assessment turned out to be small (f^2 = 0.05), possibly due to limited variance in arousal, the sample might have been too small to detect a significant small interaction effect. On the other hand, the finding that arousal did not moderate ABM effects may reflect a true null finding. It could be that elevated levels of arousal before or during training do not enhance ABM effects. If arousal truly does not moderate ABM effects, this would imply that it does not matter whether ABM is conducted during high or low levels of arousal. This would make it unlikely that the observed differences in effect size between lab-based and internet-based ABM studies (e.g., Heeren et al., 2015; Mogoaşe et al., 2014) are due to state arousal. Recent studies proposed several other potential moderators of ABM's training effectiveness such as the cognitive load during training (Clarke et al., 2017) or the perception of ABM training (i.e, credibility; Kuckertz et al., 2019). Alternatively, it is possible that there are individual differences in the extent to which arousal plays a role in ABM's effectiveness. For example, whereas some individuals may experience boredom, or neutral mood state, during ABM training and hence need provocation of arousal in order to maintain training engagement, others' learning process may be disturbed by a stressor as they already experience elevated levels of arousal. Although arousal before and during training may not moderate training effects of ABM, arousal levels may still play a role during consolidation of the training contingency. Namely, studies on learning and memory suggest that stress can either enhance or impair learning dependent on in which stage of learning (i.e., encoding, consolidation, or retrieval) stress is induced (e.g., Smeets, Otgaar, Candel, & Wolf, 2008). In order to draw firmer conclusion on whether ABM effects are moderated by arousal, it is important for future studies to induce stronger differences in arousal (e.g., by using a stronger manipulation) to test the moderating role of arousal in ABM effects in more optimal conditions.

Contrary to some previous studies (e.g., de Voogd et al., 2016; de Voogd, Wiers, & Salemink, 2017; Waters, Pittaway, Mogg, Bradley, & Pine, 2013, but see; Waters et al., 2015; Platt, Murphy, & Lau, 2015), visual search ABM was not more effective than its control version in reducing attentional bias immediately after training or one day after. One possible explanation for the lack of ABM effects on bias might be that there have been too few trials for the training to exert an effect on bias. While studies administering a single session of dot-probe training have observed training effects on attentional bias (e.g., Amir, Weber, Beard, Bomyea, & Taylor, 2008; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002), most studies that used the visual search paradigm only observed training effects on attentional bias after administering at least two sessions (e.g., de Voogd et al., 2014; 2016; 2017; Waters et al., 2013; but see Dandeneau & Baldwin, 2004). In line with this idea, one study suggested that participants significantly improved their performance during dot-probe training up to 200 trials (Abend, Pine, Fox, & Bar-Haim, 2014), while our training session consisted of only 144 trials; though it is an open question whether insights from dot-probe training can be directly translated to visual search training. As especially high anxious participants have difficulties with training their attention away from threat (Abend et al., 2014), also in the case of the visual search paradigm more trials might be needed to learn the training contingency.

Another possible explanation for the lack of ABM effects on bias is that our bias assessment did not capture actual changes in bias. Specifically, changes in attentional bias might only be captured when the bias is assessed in an anxious and aroused state, even more so when the training (i.e., encoding phase) is performed in an anxious and aroused state (Bower, 1981). Accordingly, previous studies suggested that the strength of cognitive biases varied depending on whether social stress was induced or not (e.g., Amir et al., 1996; Garner et al., 2006). Therefore, the emotional state during bias assessment should be taken into account as well. Furthermore, it can be argued that although the visual search task was relatively acceptable in terms of its internal consistency (Kline, 1999), the visual search task may not be sensitive in assessing attentional biases in students with social anxiety as there were no correlations between attentional bias and social anxiety in the current study (see also, de Voogd et al., 2016; 2017; Waters et al., 2015). Note that the 95% confidence intervals of the Spearman-Brown reliability estimates ranged from poor to good (r = 0.42-0.85) and hence should be interpreted with caution. This in line with Van Bockstaele et al. (2019) who observed that the (relevant feature) visual search task has an acceptable reliability but is not related to explicit measures of social anxiety in student samples. As bias measures vary remarkably in the extent to which they correlate with measures of anxiety (Van Bockstaele et al., 2019), future studies should include different measures of bias and anxiety in order to delineate whether ABM affected specific components of bias and anxiety or resulted in more general changes in bias and anxiety (cf. Mogg et al., 2017).

The current study has several limitations that need to be addressed. First, our manipulation procedure did not result in significant between-condition differences in arousal. As participants were informed prior to the experiment that the experiment would involve presentation tasks (due to ethical reasons), this might have limited the effects of the manipulation. Other possible reasons why the arousal manipulation may not have worked has to do with the manipulation itself. It could be that some students did not believe that they would really have to deliver a speech after the training. Future studies could use an acute stressor prior to the training to more effectively induce arousal. Moreover, as ABM might offer a form of distraction from the stressor, future studies could repeat the stressor throughout the training in order to reinstate the previously induced state of arousal. Finally, we assessed arousal solely by a self-report measure while some studies show that self-report measures are not always associated with actual physiological arousal in individuals with social anxiety (e.g., Mauss, Wilhelm, & Gross, 2004). Hence, including physiological measures of arousal can complement self-report measures and the degree to which both measures are discrepant might be an indicator of social anxiety severity (i.e., social anxiety might be characterized by a distorted perception of physiological arousal, Mauss et al., 2004).

To the best of our knowledge, this is the first study that investigated whether subjective arousal levels before and during training moderated ABM effects in reducing attentional bias, stress reactivity, and post-event processing. The findings suggested that visual search ABM was not more effective than ABM control in reducing attentional bias, stress reactivity, and post-event processing. Importantly, the findings tentatively suggested that only under elevated levels of arousal visual search ABM was more effective than its control version in reducing attentional bias. However, this effect was not maintained one day after the training. More studies are needed to replicate this preliminary finding and to investigate the moderating role of arousal and anxiety in more optimal conditions, namely with more training sessions or trials and more effective mood induction procedures.

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