Emotion in Motion: A gamified approach for the modification of attentional bias.

*Original paper*

Dr Lies Notebaert\(^1\)
Dr Ben Grafton\(^1\)
Dr Patrick J.F. Clarke\(^{1,2}\)
Dr Daniel Rudaizky\(^1\)
Dr Nigel T.M. Chen\(^2\)
Prof Colin MacLeod\(^1\)

\(^1\)Centre for the Advancement of Research on Emotion, School of Psychological Science, University of Western Australia, Australia

\(^2\)School of Psychology and Speech Pathology, Curtin University, Australia

Corresponding Author: Dr Lies Notebaert, School of Psychological Science, University of Western Australia, 35 Stirling Highway, Crawley 6009, Australia. Tel: +61 8 6488 8080, e-mail: lies.notebaert@uwa.edu.au
Abstract

Background: Individuals with heightened anxiety vulnerability tend to preferentially attend to emotionally negative information, with evidence suggesting this attentional bias makes a causal contribution to anxiety vulnerability. Recent years have seen an increase in the use of attentional bias modification (ABM) procedures to modify patterns of attentional bias, however often this change in bias is not successfully achieved.

Objectives: The current study presents a novel ABM procedure, Emotion-in-Motion, requiring individuals to engage in patterns of attentional scanning and tracking within a gamified complex and dynamic environment. We aimed to examine the capacity of this novel procedure, as compared to the traditional probe-based ABM procedure, to produce a change in attentional bias and result in a change in anxiety vulnerability.

Methods: We administered either an attend-positive or attend-negative version of our novel ABM task or the conventional probe-based ABM task to undergraduate students (N=110). Subsequently, participants underwent an anagram stressor task, with state anxiety assessed prior to and following this stressor.

Results: Whereas the conventional ABM task failed to induce differential patterns of attentional bias or affect anxiety vulnerability, the Emotion-in-Motion training did induce a group difference in attentional bias \((P = .003, \text{Cohen’s } d = 0.87)\), and differentially affected anxiety vulnerability \((P = .032, \text{Cohen’s } d = 0.60)\).

Conclusions: Our novel, gamified Emotion-in-Motion ABM task appears more effective in modifying patterns of attentional bias and anxiety vulnerability. Candidate mechanisms
contributing to these findings are discussed, including the increased stimulus complexity, dynamic nature of the stimulus presentation, and enriched performance feedback.

Keywords: Attentional bias; Anxiety Disorders; Experimental Games
Introduction

We operate in a complex and dynamic world in which we are continuously confronted with an ever-changing stream of perceptual information. The limited capacity of our cognitive system means we can only attend to certain information, while other information is filtered out. Such filtering does not operate in the same manner across all individuals, however, and it has become clear that there is a relationship between such attentional selectivity and individual differences in emotional vulnerability [1]. Specifically, research has shown that elevated anxiety vulnerability, whether indicated by elevated levels of trait anxiety or the presence of anxiety pathology, is associated with an attentional bias that favours the processing of negative information [c.f. 2]. Moreover, studies that have manipulated patterns of attentional bias (using Attentional Bias Modification, or ABM procedures) have shown that attentional bias causally contributes to anxiety vulnerability, as a change in attentional bias produces a consequent change in anxiety vulnerability [e.g. 3, 4-6].

The observation that ABM tasks delivered in the laboratory can exert a beneficial impact on anxiety responses to stressor has led a number of researchers to investigate whether extended exposure to such ABM training can reduce anxiety dysfunction in real-world settings. The most frequently used ABM procedure is based on the dot probe task [7]. In this task, participants are briefly exposed to stimulus pairs, consisting of one negative and one non-negative stimulus, before a small visual probe is presented which participants are required to identify. A contingency between the position of the probes and the position of the negative stimuli is introduced, whereby probes are either always presented in the location where the non-negative stimulus was just displayed (encouraging the adoption of an attentional bias away from negative information), or else probes are always presented in the location where the negative stimulus was just displayed (encouraging the adoption of an
attentional bias towards negative information). There is now a substantial body of evidence showing that such ABM tasks, configured to reduce attentional bias to negative information, can attenuate the symptoms of social anxiety disorder [8, 9], generalised anxiety disorder [10, 11], and subclinical obsessive compulsive symptoms [12].

While such encouraging findings highlight the potential clinical benefits of ABM procedures, it is important to recognize that in a number of ABM studies, the intended attentional training procedure has failed to affect emotional vulnerability [13-16]. Overall, meta-analyses show that the clinical effectiveness of the implementation of ABM procedures is small but nonetheless significant [17-21]. However, careful consideration of this literature suggests a clear pattern. In the studies where the intended ABM procedure successfully changed attentional bias, this produced a medium sized and significant effect on emotional vulnerability. In contrast, in studies where the intended ABM procedure did not change attentional bias, no significant impact on emotional vulnerability was observed [22-26]. These results indicate that future research efforts should focus on developing more effective procedures than the dot-probe task to modify attentional bias [27-29]. Moreover, researchers have raised concerns about the suitability of the conventional probe-based training task for use with clinical cohorts, because of its monotonous nature and low face validity [27].

In recent years, some investigators sought to adapt existing ABM procedures to make them more engaging by introducing gaming elements. Often, however, the resulting training protocols have been variants of the original probe approach, and all these protocols share in common the limitation that they seek to train attentional selectivity using very simple static displays that typically present only one or two stationary emotional stimuli [e.g. 28, 30, 31-33]. This contrasts markedly with real-world settings, which generally require individuals to engage in patterns of attentional scanning and tracking within a complex and dynamic environment [34]. In addition, these studies have been hampered by design limitations. In
some cases, the above studies have lacked a control condition [31, 32]. Moreover, in all but one case [28], these novel procedures have been delivered in a studies that afford no opportunity to compare their efficacy to that of the conventional probe-based ABM approach. Consequently, these studies leave unknown whether these novel ABM tasks can achieve attentional bias change under conditions where the conventional probe-based ABM task fail to do so, or whether such novel task can produce change in anxiety vulnerability when such change is not elicited by conventional probe-based ABM approach.

These studies did however incorporate different gamification elements to enhance engagement with the tasks in order to improve their effectiveness in modifying attentional bias [35, 36]. Some studies have included motivating feedback or goal metrics, in the form of real-time visual performance feedback and/or points [30, 33], or block-by-block feedback on performance [28]. Others have implemented more elaborate displays or a game-shell in order to increase intrinsic motivation [e.g. 31, 33, 37-41]. Another element thought to increase intrinsic motivation is goals direct learning, which directs players to particular goals to increase targeted skills [e.g. through instructing participants to attend to positive information; 42]. However, despite inclusion of these gamification elements, the majority of these studies continue to rely on either relatively sparse, or mostly static, stimulus displays.

The objective of the present study was to develop and evaluate a novel candidate ABM procedure designed to modify attentional selectivity within a task setting that, like most real world contexts, requires participants to selectively distribute attention while processing a complex and dynamic emotional environment. The task required participants to search for and track one particular target stimuli among multiple moving distractors based on their emotional valence. This complex and dynamic display thus realizes the elaborate display gamification element. The task also incorporated the gamification elements of motivating feedback, through a game-by-game high score that participants were encouraged to try to
beat, as well as the element of goals direct learning, as participants were explicitly instructed to track one particular emotional expression. Our primary aim was to evaluate the capacity of this new candidate ABM procedure, which we have labelled the Emotion-in-Motion task, to induce a group difference in selective attentional responding to negatively and positively valenced information, and to causally impact on anxiety vulnerability, as evidenced by the strength of state anxiety responses to a controlled laboratory stressor. We also delivered the conventional probe-based ABM procedure, used in most previous studies, to a separate cohort of similar participants, under equivalent laboratory conditions.

This study design will enable us to determine (1a) whether both the conventional probe-based ABM task and this new complex dynamic Emotion-in-Motion ABM task produce a group difference in attentional bias in line with the allocated attentional training condition; (1b) if both tasks prove capable of so modifying attentional bias, whether the Emotion-in-Motion ABM task impacts on attentional bias to an equal or greater degree than does the conventional probe-based ABM task; (2a) whether both the conventional probe-based ABM task and this new complex dynamic Emotion-in-Motion ABM task serve to induce a group difference in anxiety vulnerability as a function of allocated training condition, and (2b) if both tasks prove capable of so influencing anxiety vulnerability, whether the Emotion-in-Motion ABM task impacts on anxiety vulnerability to an equal or greater degree than does the conventional probe-based ABM task.

**Method**

**Participants**

One hundred and twenty-nine undergraduate students at the University of Western Australia completed the study. In line with previous research, participants who did not show
an elevation in state anxiety in response to the intended stressor were excluded prior to analyses [28]. This led to the exclusion of 19 participants, with 110 participants remaining. Participant characteristics are shown in Table 1.

**Conventional probe-based attentional tasks.**

Fifty-five participants completed the conventional probe-based bias training and assessment tasks. These participants were randomly assigned to either an attend-positive or attend-negative training condition. Participants assigned to these two conditions of the probe-based tasks did not differ significantly in age, trait anxiety scores, or gender (all \( p > .05 \)).

**Emotion-In-Motion attentional tasks.**

Fifty-five participants completed our novel Emotion-In-Motion bias training and assessment tasks. Participants were randomly assigned to either an attend-positive or attend-negative training condition. Participants to these two conditions of the Emotion-in-Motion tasks did not differ significantly in age or trait anxiety scores (both \( p > .05 \)). These two groups did differ significantly in gender ratio, \( p = .033 \), with a higher proportion of males in the attend-negative condition than in the attend-positive condition. Consequently, we considered gender ratio as a covariate in our analyses of the data, which provided reassurance that observed effects of this experimental manipulation remained evident were this group difference in gender ratio was accounted for.

*Table 1. Age, gender, and trait anxiety scores (using the STAI-T) for participants completing the conventional probe-based and the Emotion-In-Motion attentional tasks in each of the two training conditions.*

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>Trait anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(F/M)</td>
<td></td>
</tr>
</tbody>
</table>
### Conventional Probe tasks

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean (SD)</th>
<th>Correct Rate</th>
<th>Reaction Time (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend-negative (N=27)</td>
<td>19.33 (2.86)</td>
<td>14/13</td>
<td>38.44 (8.14)</td>
</tr>
<tr>
<td>Attend-negative (N=27)</td>
<td>19.50 (2.60)</td>
<td>19/9</td>
<td>41.18 (11.08)</td>
</tr>
</tbody>
</table>

### Emotion-in-Motion tasks

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean (SD)</th>
<th>Correct Rate</th>
<th>Reaction Time (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend-negative (N=28)</td>
<td>19.78 (3.62)</td>
<td>17/10</td>
<td>47.18 (8.18)</td>
</tr>
<tr>
<td>Attend-positive (N=27)</td>
<td>18.50 (0.95)</td>
<td>23/3</td>
<td>43.22 (9.24)</td>
</tr>
</tbody>
</table>

### Materials

#### Attentional tasks stimuli.

The face stimuli for the attentional tasks were selected from the Karolinska Directed Emotional Faces (KFED) stimulus set [43]. These images were cropped to show only the face and the neck. The face stimuli for the training tasks were photos of 32 individuals, half of them female and half male. For the assessment tasks, photos of 8 different individuals were selected, half of them male, half female. There were two photographs of each individual, one in which they depicted a happy expression and one in which they depicted an angry expression. Each photograph was 258 pixels (width) by 323 pixels (height). For the Emotion-in-Motion Training task, the 32 identities were grouped into eight stimulus subsets, each containing the photos of eight identities, four female and four male. Each stimulus subset was used in one of the eight blocks delivered in this Emotion-in-Motion task.

#### Emotion-in-Motion attentional bias modification task.
The aim of this task was to induce, in a complex and dynamic task environment, selective attending to angry or happy faces, depending on the assigned training condition. To provide readers with a first-hand impression of this Emotion-in-Motion task, the task can be viewed online [44].

The Emotion-in-Motion ABM task consisted of eight 3.5 min blocks or ‘games’. During each block, eight placeholder rectangles moved dynamically around the screen over a black background. Each rectangle contained an image of a face, each with a different identity. At all times, the target rectangle displayed a face with an emotional expression that differed from the emotional expressions displayed by the faces in all seven other rectangles on screen, and participants were required to attend to and track this rectangle. In the ‘attend-negative’ condition, the target rectangle displayed a face with an angry expression while the other rectangles displayed faces with happy expressions. In the ‘attend-positive’ condition, the target rectangle displayed a face with a happy expression while the other seven rectangles displayed faces with angry expressions. Participants were instructed to find the target rectangle and track it using the mouse cursor. All the rectangles, including the target, constantly switched faces. Participants were instructed to keep tracking the target rectangle (i.e. depicting the single face with the expression differing from that of the other seven faces) even the face presented within changed, as long as the emotional expression of the face presented remained the same (i.e. when the face in the target rectangle switched to a different identity, participants were required to keep tracking the rectangle as long as the emotional expression of the new face was the same as the emotional expression of the previous face). At random intervals, the emotional expression of a target face would change in addition to its identity, at which point this ceased to be the target rectangle. At that same moment, one of the other rectangles would assume a face depicting this emotion, and so identifying it as the (new) target rectangle. At these points, participants had to quickly find the new target rectangle and start tracking it.
At the start of a block, each face remained constant for the first 2000ms. Thereafter, faces switched randomly between 1-2000ms throughout the block. Within each block, the target rectangle switched 60 times, at random intervals of between 5-10 seconds. All 8 rectangles moved with different randomly determined trajectories, at a randomly determined speed of between 30 and 50 pixels per 100ms. Thus, although the rectangles moved at different speeds, each rectangle’s speed was constant within a game. The rectangles bounced off the screen edges and other stimuli they contacted at an angle of reflection that matched their angle of incidence. The target rectangle was never indicated, however when the mouse cursor was correctly located in the position of the current target rectangle, this cursor disappeared “behind” the rectangle (to not obscure the face presented within) and remained hidden so long as the participant kept it on target.

The onset of each block was preceded by a three second countdown presented in the centre of the screen. At the end of each block, participants were presented with a tracking score (i.e., the percentage of time during that game they were tracking the target rectangle), a switching score (i.e., the average speed to which the participant was able to shift their cursor to the next target rectangle), and a total score for that block (generated by combining the tracking score and the switching score). The screen also displayed the participant’s highest prior (total) score. Participants were encouraged to beat their current high score on each successive block.

**Emotion-in-Motion attentional bias assessment task.**

The training contingency was removed from the Emotion-in-Motion training task, to create the assessment task used to reveal the impact of this training on attentional selectivity. Thus, participants were required to track a rectangle displaying a face with a happy expression (among 7 rectangles displaying faces with angry expressions) on half of the blocks, and to track a rectangle displaying face with an angry expression (among 7 rectangles...
displaying faces with happy expressions) on the other half of the blocks. This assessment task delivered 12 short blocks, each of which contained 5 target switches, resulting in a total of 60 target switches across the assessment task. In six of these blocks, the target rectangle displayed a face with an angry emotional expression, and in 6 blocks the target rectangle displayed a face with a happy emotional expression. The order of these block conditions was randomly determined, with the constraint that a maximum of 2 consecutive blocks could have a target with the same valence. Each block started with a 5 second count down.

To obtain a measure of attentional bias to negative information, an attentional bias index (ABI) was computed by subtracting the average tracking score a participant obtained in blocks where targets were happy faces from the average tracking score the participant obtained in blocks where targets were angry faces. Therefore, a higher positive score on this index reflects greater attention to negative information, as it represents more successful tracking of angry than of happy faces.

Other experimental tasks.

The Trait Anxiety Assessment, Conventional probe-based attentional bias modification and assessment tasks, as well as the Anxiety reactivity assessment task, are described in Appendix.

Procedure

Participants were tested individually in a sound-attenuated room. Once informed consent from participants had been obtained, participants were instructed to sit at a comfortable viewing distance from the computer screen (approximately 60cm), were given instructions, and completed the first assessment task. After completion of the training task, they completed the original assessment task again. Next, participants completed the anxiety reactivity assessment task containing an anagram stressor task preceded and followed by a
measure of state anxiety. At the end of the session, participants were debriefed about the purpose of the study. The entire experimental session lasted about 1 hour. This study was approved by the University of Western Australia’s Human Research Ethics Committee, protocol RA415243.

Results

Impact of Attentional Training Procedure on Attentional Bias

The criteria to identify outliers are described in Appendix. The attentional bias index scores obtained before and after the training task are shown in Table 2.

Conventional probe-based training.

Application of the outlier criteria led to the exclusion of four participants. To examine whether the conventional probe-based training task was capable of modifying attentional bias, a mixed methods ANOVA was performed with the within-subjects factor Attentional Assessment Point (Pre-training Assessment, Post-training Assessment), and the between-subjects factor Training Condition (Attend-Positive training, Attend-Negative training). The Attentional Bias Index (ABI) scores obtained by participants who completed this conventional probe-based training task served as the dependent variable.

Results showed neither a significant main effect of Attentional Assessment Point, $F < 1$, nor of Training Condition, $F(1,48) = 2.246, P = .141$. Most importantly, the critical interaction between Attentional Assessment Point and Training Condition fell short of significance, $F(1,48) = 3.018, P = .089, \eta_p^2 = 0.059$. 

13
Table 2. Attentional bias index scores pre and post training for participants who completed the conventional probe-based attentional bias training and assessment tasks or the Emotion-in-Motion attentional bias training and assessment tasks, in either the attend-positive training condition or the attend-negative training condition.

<table>
<thead>
<tr>
<th></th>
<th>Attend-positive condition</th>
<th>Attend-negative condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Conventional probe training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABI Pre training</td>
<td>5.669</td>
<td>50.752</td>
</tr>
<tr>
<td>ABI Post training</td>
<td>15.101</td>
<td>45.33</td>
</tr>
<tr>
<td>Emotion-in-Motion training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABI Pre training</td>
<td>0.449</td>
<td>6.041</td>
</tr>
<tr>
<td>ABI Post training</td>
<td>2.739</td>
<td>6.545</td>
</tr>
</tbody>
</table>

Application of the outlier criteria led to the exclusion of three participants. To determine whether our novel Emotion-in-Motion attentional training procedure was effective in modifying attentional responding to negative information, the Attentional Bias Index (ABI) scores obtained by participants who completed this task were subjected to a mixed-design 2 x 2 ANOVA that again considered the within-group factor Attentional Assessment Point (Pre-training Assessment vs. Post-training Assessment), and the between-group factor Training Condition (Attend-Positive training vs. Attend-Negative training). This analysis revealed a significant main effect of Training Condition, $F (1, 50) = 4.602, P = .037, \eta^2_p = .084$, subsumed within a higher-order interaction of Attentional Assessment Point x Training Condition, $F (1, 50) = 5.629, P = .022, \eta^2_p = .101$. At pre-training, there was no significant difference between the attentional bias index scores obtained by participants in the attend-positive training condition and participants in the attend-negative training condition, $F < 1$. In contrast, at post training, participants in the attend-negative training condition showed a significantly higher attentional bias index scores as compared to participants in the attend-

positive condition, \( F(1,50) = 9.903, \ P = .003 \), Cohen’s \( d = 0.87 \). While the change in attentional bias from pre to post training fell short of significant for participants in the attend-negative training condition, \( t(25) = -1.162, \ P = .256 \), Cohen’s \( d = 0.229 \), there was a significant change from pre to post training for participants in the attend-positive training condition, \( t(25) = 2.114, \ P = .045 \), Cohen’s \( d = 0.415 \). Overall, this pattern of results confirms that the two training conditions exerted a differential impact on attentional bias to negative information, and the direction of the observed attentional training effects were as expected. When controlling for the gender, by adding this as a covariate, this interaction between Attentional Assessment Point and Training Condition remained significant, \( F(1,43) = 4.393, \ P = .042 \), \( \eta^2_p = .087 \).

Impact of Attentional Training Procedure on Anxiety Vulnerability

The state anxiety scores obtained using the analogue mood scale given before and after the final anagram stressor are shown in Table 3.

Table 3. State anxiety scores pre and post anagram stressor for participants who previously completed the conventional probe-based attentional bias training task, or the Emotion-in-Motion attentional bias training task, in either the attend-positive training condition or the attend-negative training condition.

<table>
<thead>
<tr>
<th></th>
<th>Attend-positive condition</th>
<th>Attend-negative condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional probe training</td>
<td>( M )</td>
<td>( SD )</td>
</tr>
<tr>
<td>State Anxiety Pre training</td>
<td>30.680</td>
<td>10.858</td>
</tr>
<tr>
<td>State Anxiety Post training</td>
<td>43.600</td>
<td>9.734</td>
</tr>
<tr>
<td>Emotion-in-Motion training</td>
<td>( M )</td>
<td>( SD )</td>
</tr>
<tr>
<td>State Anxiety Pre training</td>
<td>31.292</td>
<td>10.149</td>
</tr>
<tr>
<td>State Anxiety Post training</td>
<td>39.458</td>
<td>11.026</td>
</tr>
</tbody>
</table>
**Conventional probe-based training.**

Application of the outlier criteria led to the exclusion of one participant. To examine whether the two training conditions had a differential impact on anxiety reactivity, state anxiety scores were subjected to a mixed methods ANOVA with the within-subjects factor State Anxiety Assessment Point (Pre-Stressor Assessment vs. Post-Stressor Assessment), and the between-subjects factor Training Condition (Attend-Positive Training vs Attend-Negative Training). Results showed a significant main effect of State Anxiety Assessment Point, $F(1, 48) = 159.991, P < .001$, indicating that state anxiety increased from before the anagram stressor ($M = 28.440, SD = 11.639$) to after the anagram stressor ($M = 42.020, SD = 10.729$). However, neither the main effect of Training Condition, $F(1, 48) = 1.664, P = .203$, not the critical interaction between State Anxiety Assessment Point and Training Condition, $F(1, 48) = .378, P = .542, \eta^2_p = 0.008$, were significant.

**Emotion-in-Motion training.**

Application of the outlier criteria led to the exclusion of four participants. The same 2x2x2 ANOVA as reported above was conducted on state anxiety scores to examine whether in participants who completed the Emotion-in-Motion training procedure, the two training conditions had a differential impact on anxiety reactivity. This analysis revealed a significant main effect of State Anxiety Assessment Point, $F (1, 46) = 125.99, P < .001, \eta^2_p = .73$, again reflecting the fact that state anxiety increased from before the stressor ($M = 30.58, SD = 10.87$) to after the stressor ($M = 40.54, SD = 10.88$). This main effect now was subsumed within a significant two-way interaction of State Anxiety Assessment Point and Training Condition, $F (1, 46) = 4.39, P = .042, \eta^2_p = .09$. Follow-up t-tests revealed that immediately following the attentional training procedure but before the anagram stressor experience,
participants who had received the two training conditions did not differ in their levels of state anxiety, $F(1, 46) = .31, P = .583, \eta^2_p = .01$. Participants in each Emotion-in-Motion attentional training condition responded to this stress manipulation by displaying an elevation in anxious mood state (attend-positive training: $F(1, 23) = 55.84, P < .001, \eta^2_p = 0.71$ vs. attend negative training: $F(1, 23) = 70.56, P < .001, \eta^2_p = 0.76$). However, the magnitude of the elevation in state anxiety evoked by this stressor was significantly attenuated in those participants who had received the Emotion-in-Motion attend-positive attentional training, compared to those participants who had received the Emotion-in-Motion attend-negative attentional training condition ($M = 8.17, SD = 5.35$ vs. $M = 11.92, SD = 6.94$; Cohen’s $d = 0.60$). Thus, those participants who had been exposed to the Emotion-in-Motion task training contingency designed to reduce attentional bias to negative information subsequently came to display relatively attenuated elevations of anxious mood state in response to the anagram stressor experience compared to participants who had been exposed to the training condition designed to increase attentional bias to negative information. When controlling gender, by adding gender as a covariate, this interaction between State Anxiety Assessment Point and Training Condition remained significant, $F(1,43) = 4.638, P = .037, \eta^2_p = .097$.

**Discussion**

The objective of this study was to develop and evaluate a novel attentional bias modification (ABM) procedure, intended to systematically alter selective attentional responding to emotional information in a complex and dynamic task environment. Our results showed that our novel Emotion-in-Motion training procedure succeeded in modifying patterns of attentional bias, as intended. Moreover, those participants who were allocated to the attend-positive condition of the Emotion-in-Motion attentional training task showed reduced anxiety reactivity to the subsequent lab-based stressor as compared to participants.
who were allocated to the attend-negative condition of this task. These results suggest that our novel attentional training task appeared capable of modifying both patterns of attentional bias, and causally influencing anxiety vulnerability.

A subsidiary aim was to permit comparison with the conventional probe-based attentional bias training procedure. Under equivalent laboratory conditions, the conventional probe-based attentional training approach failed to induce differential patterns of attentional bias, and the two probe-based training conditions did not lead to participant differences in anxiety reactivity to the subsequent stressor. In recent years, several studies (including three out of our lab) have reported similar failures of the conventional probe-based attentional training task to successfully modify patterns of attentional bias [e.g. 28, 45-49], therefore it is reasonable to conclude that the probe-based ABM procedure may be a non-optimal way of achieving bias change.

In reflecting on the reasons for the capacity of our novel Emotion-in-Motion paradigm to induce differential patterns of attentional bias, under conditions where the conventional probe-based training did not, several candidate factors can be considered. Firstly, the Emotion-in-Motion task presents eight stimuli simultaneously, whereas the conventional probe task displays only two stimuli. There is some evidence that attentional bias is more pronounced when assessed using visual displays that contain more stimuli [50, 51], but as yet it is unknown whether more robust attentional bias modification effects can be obtained using paradigms that present more stimuli. Although there already exist some training procedures that involve more complex stimulus displays [e.g. 39, 52], as yet no direct comparison between the effectiveness of training tasks using simple versus complex stimulus displays has been made. In future research, the Emotion-in-Motion paradigm can be easily be adapted to present simple displays (e.g. two rectangles) versus complex displays (e.g. eight rectangles), to enable such comparison.
A second candidate factor which could have contributed to the findings observed with the Emotion-in-Motion approach is the dynamic nature of the stimulus presentation. In the Emotion-in-Motion task, all stimuli move dynamically around the display, whereas in other attentional training paradigms stimuli are presented in a static manner. It is possible that the dynamic nature of Emotion-in-Motion enhanced concentration and engagement with the task, thereby increasing its capacity to deliver the intended attentional bias change. In future research the potential contribution of this dynamic component could be examined by contrasting task variants that employ the present dynamic approach with variants that instead present the same number of stimuli in static grid.

A third candidate reason for its efficacy may be the provision of enriched performance feedback in the Emotion-in-Motion task, compared to the rudimentary trial-by-trial error feedback given in the conventional probe-based attentional training task. Block feedback of the type delivered in the Emotion-in-Motion task has been shown to enhance learning in simple repetitive tasks [53], and may have also contributed to enhanced performance in the Emotion-in-Motion task. Future research could further examine the contribution of enriched performance feedback to the efficacy of ABM procedures, by comparing conventional probe-based training with and without such block feedback, or by manipulating whether or not the presently provided block feedback is delivered within the Emotion-in-Motion task.

The enhanced performance feedback, as well as the complex and dynamic nature of the task, could have resulted in greater engagement with the Emotion-in-Motion task, relative to the conventional probe task. In addition, the tracking response required in the Emotion-in-Motion task is continuous, while the probe task only requires a response every couple of seconds. Task engagement can be conceptualised as a combination of energy, motivation, and concentration, and can be measured using self-report as well as through task performance indicators [54]. In the current task, we did not obtain self-report measures of task
engagement, and the difference in the nature of the tasks leaves us unable to compare performance indicators of engagement. However, future research may usefully examine whether individuals so show a difference in engagement with the Emotion-in-Motion task relative to the probe task, and whether task engagement moderates the procedures’ impact on attentional bias and anxiety vulnerability [55].

It is important to consider the potential limitations of the current study. One such limitation is that the capacity of the Emotion-in-Motion training task, and the capacity of the conventional probe-based training task, to modify attentional bias were each established using a different method of assessing attentional bias. For both training tasks, the assessment approach involved delivering the same task but with the training contingency removed. This design critically allows for comparable demonstration of near transfer across the two training tasks. However, it does preclude direct comparison of attentional bias change observed in response to circumvent this limitation each of these two candidate attentional training approaches. Future research could circumvent this limitation by employing the same attentional bias assessment approach(es) for all ABM tasks under evaluation.

A second potential limitation is that the current study was carried out on an undergraduate non-clinical participant sample. While this design allowed us to examine whether the Emotion-in-Motion procedure can induce differential patterns of attentional bias, and consequently test the causal impact of these differential patterns of attentional bias on anxiety vulnerability, it does limits conclusion concerning either the acceptability or the efficacy of our novel Emotion-in-Motion ABM approach when used with a clinical sample. While the complex and dynamic nature of the Emotion-in-Motion task can be expected to enhance face validity of and engagement in the task, future research using clinical cohorts will be necessary to determine whether this novel ABM task is more acceptable to patients samples than the conventional probe-based training task.
In the meantime, we hope that the Emotion-in-Motion task, which the present study has shown to be capable of modifying attentional bias to emotional information, and altering anxiety vulnerability as indicated by anxiety reactivity to a stressor, will be of interest and potential value to researchers investigating the potential anxiolytic benefits of directly manipulating maladaptive patterns of attentional bias. To facilitate further research using this task, and to encourage independent replication of the current findings, we made our Emotion-in-Motion task software freely available [Ref to be provided]. While we look forward to the future evaluation of this novel ABM approach in other cohorts and settings, we also encourage fellow researchers to develop and refine new and innovative attentional bias modification paradigms that further enhance our capacity to modify the attentional bias to negative information implicated in anxiety vulnerability and dysfunction. Such continuous improvement in our attentional bias modification approaches will optimize the prospect of developing future ABM protocols that prove capable of delivering robust and reliable therapeutic benefits within the clinic.
References


Conflict of interest:

The authors report no conflicts of interest.

Acknowledgements:

LN is supported by the Australian Research Council under Grant DP140104448. CM is supported in part by a grant from the Romanian National Authority for Scientific Research, CNCS–UEFISCDI, project number PNII-ID-PCCE-2011-2-0045. PJFC was supported by Australian Research Council Grant DP140103713. BG is supported in part by Australian Research Council Grant DP170104533. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.