Attention bias modification via single-session dot-probe training: Failures to replicate

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Abstract

Background and Objectives. Across three experiments we investigated transfer effects of single-session attention bias modification via dot-probe training. **Methods**. In experiment 1, participants received training either toward or away from negative images or no-training, and transfer to an affective task-switching task was examined. In two other experiments, participants were trained to orient attention toward either positive or negative words (experiment 2a) or facial expressions (experiment 2b), and transfer to an interpretation bias task was examined. **Results**. In all experiments, the dot-probe training procedure did not effectively modify biases in attention allocation at the training condition level, but produced a large variability in individual attention bias acquisition within and across conditions. Individual differences in pre-training attention bias and attention bias acquisition were not related to performance on the affective task-switching task or the interpretation tasks. **Limitations**. The present investigations are limited by the lack of effectiveness of ABM at the condition level, the order in which transfer tasks were administered, and the restricted range of affective symptoms that could moderate training and transfer effects. **Conclusions**. The findings from three experiments provided no evidence for single-session dot-probe ABM procedures to effectively manipulate attention bias toward negative, away from negative, or toward positive stimuli at a training condition level. At the individual differences level of analysis, again no evidence was found for transfer of attention training. The observations invite further empirical scrutiny into factors that moderate attentional plasticity in response to dot-probe ABM procedures to optimize the conditions for effective implementation and transfer of training.

Keywords: dot-probe, attention training, transfer, affective task-switching, interpretation.

Highlights

- Transfer of single-session attention training was examined in three experiments
- Dot-probe training procedures did not effectively modify attentional biases
- No transfer occurred to non-trained stimuli on an affective task-switching task
- No transfer occurred to trained or non-trained stimuli on an interpretation task

1. Introduction

Emotional biases in attention are related to psychological well-being: Healthy individuals pay more attention to positive material, whereas anxious and depressed individuals predominantly attend to threatening or sad material (Peckham, McHugh, & Otto, 2010; Van Bockstaele et al., 2014). These attention biases operate at several stages in the pathogenesis of affective disorders (e.g., at subclinical or remission stages), affect an individual's response to emotionally distressing situations, and predict the course of affective symptoms over time (Cisler, Bacon, & Williams, 2009; De Raedt & Koster, 2010). Hence, attention biases seem causally involved in one's emotional state. To address its causal status, experimental procedures have been developed to manipulate emotional biases in attention allocation (Koster, Fox, & MacLeod, 2009).

A commonly-used procedure to manipulate attention bias is based on the emotional dot-probe task, originally designed to measure selective attention toward disorder-related material (MacLeod, Mathews, & Tata, 1986). A standard task design simultaneously presents two stimuli (e.g., one disorder-related, one neutral) for a brief duration (e.g., 500 ms) at either side of fixation. After offset, a probe (e.g., an E or F) appears with equal probability at the location of one of the stimuli. Participants are instructed to identify the probe as quickly and accurately as possible by pressing the corresponding button. Negative biases in attention are inferred from faster RTs on trials with probes replacing disorder-related stimuli (i.e., congruent trials) compared to trials with probes replacing neutral stimuli (i.e. incongruent trials). By varying the contingency between the disorder-related stimuli and the probe's location, the standard design can be adapted to induce or reduce emotional biases in attention. Using such an adapted version of the task, MacLeod and colleagues were able to induce a negative bias by consistently presenting the probe at the location of the disorder-related stimulus and, analogously, to reduce a negative bias by presenting the probe at the opposite location (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Mathews & MacLeod, 2002). Interestingly, they found that induction compared to reduction of a negative attention bias increased stress reactivity.

Building on these initial observations, numerous studies investigated the causal relation between attention bias and symptoms of emotional disorders, including studies examining whether ABM reduces symptoms of anxiety and depression. Effect sizes of attention training on affective symptoms vary strongly across meta-analyses. An early report estimated the effect size of ABM on anxiety in the medium range in nonclinical or subclinical samples, and in the medium-to-large range in clinical samples (Hakamata et al., 2010). Later reports, including a larger number of studies, found only small effect sizes of ABM training in modifying anxiety and emotional reactivity (Beard, Sawyer, & Hofmann, 2012; Hallion & Ruscio, 2011; Mogoase, David, & Koster, 2014). For depression, meta-analytic evidence suggests no effects of ABM on depressive symptomatology, but note that there is little research testing ABM in depressed samples (see Mogoase et al., 2014). While several recent ABM studies did not produce clinically significant changes (Boettcher, Andersson, Carlbring, & Group, 2013; Carlbring et al., 2012; Julian, Beard, Schmidt, Powers, & Smits, 2012; Neubauer et al., 2013; Rapee et al., 2013), such failures might be due to failures of ABM to change attentional bias at the *training condition* (group) level (Clarke, Notebaert, & MacLeod, 2014). Yet, there is large variability among trainees in attention bias acquisition following ABM delivery and such *individual differences* may predict anxiety levels (e.g., Clarke, Chen, & Guastella, 2012; Clarke, MacLeod, & Shirazee, 2008). These observations prompt researchers to consider both the training condition and individual differences level of analysis when evaluating dot-probe ABM effects.

Although ABM seems effective in reducing affective symptoms, the processes through which ABM alters these symptoms need clarification. Decreases in attention bias through training are related to reductions in affective symptoms (Mogoase et al., 2014), but this does not explain how changes in attention result in a congruent symptomatic improvement. One process that could account for this is generalization or transfer from the stimuli presented in a controlled experimental training context to non-trained disorder-relevant stimuli and mechanisms closely related to attention that are important to emotional well-being. Transfer effects of dot-probe ABM were investigated by Van Bockstaele, Koster, Verschuere, Crombez, and De Houwer (2012). In their study, participants were trained to attend either toward or away from threatening pictures, but training effects did not generalize to an emotional interference task measuring processes related to attention. These findings contradict earlier observations suggesting that dot-probe training effects generalize to a spatial cueing task, that is, conditions resembling the initial training task (Amir et al., 2009; Amir, Weber, Beard, Bomyea, & Taylor, 2008; Heeren, Lievens, & Philippot, 2011). Moreover, there is some evidence for transfer of ABM to memory. A study reported that participants with elevated depressive symptom severity levels trained to orient away from negative words did not show a negative recollection bias which was observed in control individuals (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013). In sum, research indicates that dot-probe training effects transfer to new, non-trained stimuli under similar conditions, but provides mixed evidence regarding transfer to other critical processes. The limited insight into the stimuli and processes to which ABM effects transfer warrant further empirical scrutiny.

This paper presents three experiments to investigate transfer of single-session dot-probe training. In experiment 1, we studied transfer of attention training toward and away from negative material to non-trained stimuli in an affective task-switching task. This task measures the ability to flexibly switch between affective and non-affective processing task-sets, which is a process predictive of trait resilience (Genet & Siemer, 2011). In experiment 2a and 2b, we examined transfer of training toward positive and negative material to trained and non-trained stimuli in an interpretation task requiring individuals to evaluate positive and negative self-relevant meanings. Interpretation bias, a risk factor to various emotional disorders (Mathews & MacLeod, 2005), depends on emotional biases in attention and regulates emotional memory (Everaert, Duyck, & Koster, 2014; Everaert, Tierens, Uzieblo, & Koster, 2013). In keeping with recent ABM research, we investigated effects of training on attention bias and transfer tasks at the condition as well as at the individual differences level. We expected that trained attention biases modulate the flexibility of switching between emotional and non-emotional features of non-trained stimuli and alter interpretation of emotional information.

2. Experiment 1

2.1 Methods

2.1.1 Design Overview

After the pre-training attention bias assessment, participants were randomly assigned to either a condition in which attention was trained away from negative stimuli (i.e., ‘neutral training’), toward negative stimuli (i.e., ‘negative training’), or the no-training control. Then, participants completed a post-training bias assessment and the affective switching task. The experiment ended with the questionnaires. The study protocol was approved by the ethical committee at Ghent University.

2.1.2 Participants

Undergraduate students completed either the neutral (n=26), negative (n=23), or no-training (n=25) condition. All participants provided informed consent and were compensated a course credit or 8 euro.

2.1.3 Tasks and Measures

Attention training. ABM consisted of a dot-probe procedure modeled after Amir et al. (2008) and Van Bockstaele et al. (2011). On each trial, a 500 ms fixation was followed by of the presentation of two pictures (3.82° height by 5.06 width) above and below fixation for 500 ms. There was a 3.8° angle between fixation and the picture's center. After offset, a probe (E or F) replaced one picture and participants identified the probe as fast and accurately as possible by pressing the corresponding button. The next trial started 500 ms after a response was registered. Participants were seated approximately 60 cm from the monitor.

There were three different trial types. First, *digit trials* presented numbers from 1 to 6 at the screen's center requiring participants to manually report the digit. This was to check whether participants maintained gaze on fixation throughout the task. Second, *emotional trials* presented negative-neutral picture pairs preceding the probe (e.g., a snake and a dryer). Trials were considered incongruent when a probe replaced the neutral picture and congruent when a probe replaced the negative picture. Third, *neutral trials* presented only neutral picture pairs before the probe (e.g., a book and a cup).

The full ABM procedure comprised four phases. First, a *practice phase* of 24 neutral and 3 digit trials served to familiarize participants with the task. In a subsequent *pre-training phase*, 96 emotional trials (48 congruent, 48 incongruent), 24 neutral trials, and 6 digit trials were presented in random order. Next, in the *training phase*, 288 experimental, 72 neutral, and

18 digit trials were presented in random order equally dispersed over 3 blocks. Depending on the training condition, experimental trials depicted only emotionally congruent (‘negative training’), incongruent (‘neutral training’) or an equal amount of congruent and incongruent (‘no-training’) trials. In a *post-training phase*, 96 emotional trials (48 congruent, 48 incongruent), 24 neutral trials, and 6 digit trials were presented. As stimuli, 12 negative and 12 neutral scenes were used for assessment and training, and 6 additional neutral scenes were used for practice. The stimuli were pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) drawn from Van Bockstaele et al. (2012).

Flexible affective processing. An affective task-switching task was modeled after Genet and Siemer (2011). The task presented emotional pictures against a red or blue background which served as cue to prompt participants to categorize the picture according to the affective (Is the picture content positive or negative?) or non-affective (Is the picture content an animate or inanimate?) rule. For example, participants applied the affective rule when the background colored blue, and the non-affective rule when the background colored red. On each particular trial, one rule was active and the other non-active. Participants were instructed to categorize the picture as fast and accurately as possible by pressing a key. The categories were spatially mapped on to the ‘E’ and ‘F’-key. For example, animate and positive were mapped on to ‘E’ and inanimate and negative were mapped on to ‘F’. The category-key mappings and cue-rule linkages were counterbalanced across participants.

Trials were divided into one consistent and one inconsistent block depending on whether responses to the affective and non-affective rule were mapped on to consistent or inconsistent response keys. In the *consistent* block, trials presented only animate positive and inanimate negative pictures such that the response associated with the non-active rule did not interfere with the correct response of the active rule. That is, the presented pictures required participants to press the same key regardless of the cued rule (e.g., ‘F’ is correct when presented with inanimate negative pictures regardless the cued rule). In the *inconsistent* block, trials presented only inanimate positive and animate negative pictures such that responses associated with the non-active rule interfered with correct responses according to an active rule. Correct categorization responses to the active rule were mapped on to different response keys than correct responses for the non-active rule (e.g., ‘F’ is only correct when presented with animate negative pictures and cued with an affective rule) Thus, a correct response required inhibition of the response associated with the non-active rule. After a 60-trial practice with feedback, participants completed 120 consistent trials followed by 120 inconsistent trials. The processing rule alternated randomly within consistent and inconsistent blocks.[1]

Stimuli. Thirty positive and thirty negative IAPS scenes (Lang et al., 2008) were selected.[2] Half of the positive and negative pictures depicted animate and the other half inanimate scenes.

Questionnaires. Depression severity and trait anxiety were measured with the Beck Depression Inventory – II (BDI-II; Van der Does, 2002) and the Spielberger State-Trait Anxiety Inventory – ‘trait’ version (STAI-T; Van der Ploeg, Defares, & Spielberger, 2000). The questionnaires presented a series of statements (21 items in a BDI-II, 20 items in a STAI-T) to be rated on a 4-point rating scale (BDI-II: from 0 to 3; STAI-T: from 1 to 4). Both the BDI-II (Beck, Steer, & Brown, 1996; Van der Does, 2002) and the STAI-T (Spielberger, 1983) have good psychometric properties in non-clinical samples.

2.1.4 Data Preparation and Analytical Strategy

Pre and post-training data was trimmed by removing errors, RTs faster than 150 ms and slower than 1500 ms, and outlying RTs ± 3 *SD* from the individual's *M*. All participants performed satisfactory on digit trials and were included. Statistical analyses were conducted on 94% of the data. Affective task-switching task data was trimmed by removing practice trials, errors (9.9%), RTs faster than 250ms and slower than 2500ms (2.5%).

An attentional bias index for the pre and post training phase was computed by subtracting RTs on congruent trials from RTs on incongruent trials (Macleod & Mathews, 1988), with higher scores indicating a stronger negative bias. Similar to Clark and colleagues, we computed an individual bias acquisition index by subtracting the pre-training from the post-training attention bias score (Clarke et al., 2012; Clarke et al., 2008). For the affective task-switching task, repetition and switch trials were identified, and switch costs were calculated by subtracting RTs on repetition trials from RTs on switch trials for the consistent and inconsistent block.[3]

Statistical analyses were conducted at the training condition and at the individual bias acquisition level. We first tested ABM effects on attention bias at the condition level via a repeated measures ANOVA on RTs with Time (pre-training vs. post-training) and Trial Type (congruent, incongruent) as within-subjects variables and Condition (negative, neutral, or no training) as a between-subjects variable. Depending on effective ABM implementation, we followed up by examining transfer effects at the training condition level via condition-specific repeated measures analysis. Next, individual differences in transfer of training were examined via regression analysis. The regression analyses included pre-training attention bias scores (i.e., the natural propensity to attend to emotional material) and individual bias acquisition scores (i.e., the propensity to modify the natural attentional pattern) as predictors of performance on the transfer task, here the affective task-switching costs on consistent and inconsistent blocks.

2.2 Results

2.2.1 Group Characteristics

No differences among between conditions were found on age, *F*<1, BDI-II, *F*(2,71)=2.03, *p*=.14, or STAI-T scores, *F*(2, 71)=1.70, *p*=.19. The neutral and no-training condition did not differ on gender ratio, $\chi^2(1)=.21$, *p*=.65. Gender data for the negative training condition was missing (see Table 1).

2.2.2 Attention Training Effects

Repeated measure analysis yielded a main effect of Time, *F*(1, 67)=25.99, *p*<.01, with faster RTs at post-training than at pre-training (see Table 2). No other main effects were significant (*F*'s<1.68). The effect for Time × Condition, *F*(2,67)=4.280, *p*=.01, revealed significantly faster RTs at post-training than at pre-training in the neutral, *t*(23)=2.72, *p*=.01, and no-training, *t*(23)=4.81, *p*<.01, but not in the negative training condition, *t*(21)=1.06, *p*=.30. The other interaction-effects were not significant (all *F*'s<1).

2.2.3 Transfer to Affective Task-switching

Transfer effects of attention training were tested at the individual differences level across conditions given the not-successful ABM delivery at the condition level and the substantial variability in attention bias acquisition scores (across conditions: *M*=3.84, *SD*=34.62, range: -74 – 98; see Table 2 for within condition statistics). Regression analysis on consistent task-switching trials yielded no significant model fit *F*(2,67)=1.90, *p*=.15, R^2 = 5.00%, VIF=1.38, T=.72, without individual effects of pre-training attention bias, β=-.26, *p*=.06, and individual bias acquisition scores, β=-.08, *p*=.54. Similarly, neither pre-training attention bias scores, β=-.21, *p*=.13, nor individual bias acquisition scores, β=.06, *p*=.64, predicted task-switching costs on inconsistent trials, $F(2,67)=1.20$, $p=.30$, $R^2 = 3.00\%$, VIF=1.38, T=.72.

2.3 Discussion

The results yielded no effects of dot-probe ABM in modifying an attention bias at the training condition level, and individual differences in the natural tendency to process emotional material as well as individual differences in attention bias acquisition were not related to affective task-switching costs. This suggests that single-session ABM might be insufficient to induce and reduce a negative attention bias that could transfer to new emotional stimuli presented in an affective task-switching task.

3. Experiment 2a

3.1 Methods

3.1.1 Design Overview

After a pre-training attention bias assessment task, participants were randomly assigned to a condition in which attention was trained toward either negative (i.e., ‘negative training’) or positive (i.e., ‘positive training’) words. This was to track transfer from ABM to an interpretation task, a scrambled sentences test (SST; Wenzlaff & Bates, 1998) in which individuals constructed negative or positive sentences from ambiguous information. An SST was administered before the pre-training and after post-training attention bias assessment. Participants completed the questionnaires after the pre-training SST. The study protocols of experiments 2a, and 2b were approved by the institutional review board at Ghent University.

3.1.2 Participants

Undergraduate students with minimal depression levels (BDI-II scores < 14; for criteria see Beck et al., 1996; Van der Does, 2002) at the moment of testing completed either the positive (n=18) or negative (n=20) training condition. All individuals provided informed consent and received a course credit for their participation.

3.1.3 Tasks and Measures

Attention training. The ABM procedure was identical to experiment 1 with exception of the stimuli (words, not pictures) and presented stimulus pairs (negative-positive pairs, not negative-neutral pairs). Emotional trials were considered incongruent when probes replaced positive words, and congruent when probes replaced negative words. There was 2° vertical distance between the words.

Stimuli. Forty-eight word pairs were selected for the ABM task. Each pair corresponded with positive and negative words from a scrambled sentence (e.g., 'bright' and 'dismal' in 'looks the future bright very dismal'; see below). Word pairs of the pre-training SST were presented in the pre-training phase and word pairs of the post-training SST were presented in the training and post-training phase. All stimuli were displayed in white uppercase letters against a black background. The 12 neutral-neutral word pairs corresponded with neutral words from neutral scrambled sentences used in an earlier study (Everaert et al., 2014).

Transfer task. The SST assessed interpretation bias. Presented with a scrambled sentence (e.g., "looks the future bright very dismal"), participants form grammatically correct and meaningful self-relevant statements by using 5 of the 6 words. Reporting the first sentence that comes to mind, all solved items have either a positive (e.g., "the future looks very bright") or negative (e.g., "the future looks very dismal") meaning. Two matched sets of 24 scrambled sentences were drawn from Everaert et al. (2014) as a pre- and post-training bias assessment. At each assessment, participants solved as many sentences as possible within 3.5 minutes. As in prior research (e.g., Everaert et al., 2013; Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002), a cognitive load procedure was applied to reduce deliberate report strategies (e.g., social desirability). Participants memorized a 6 digit number before the SST which they had to recall after the test. The proportion of sentences solved in a negative (relative to a positive) manner served as an index of interpretation bias.

Questionnaires. Measures of depression and anxiety were identical to experiment 1.

3.1.4 Data Preparation and Analytical Strategy

Pre- and post-training data were trimmed by removing errors (4.80%), RTs faster than 150 ms and slower than 1500 ms (< 1%), and RTs ± 3 SDs from the individuals' mean score (1.30%). All participants performed satisfactory on digit trials and were included. For this experiment, a pre to post training change index for interpretation bias was computed by subtracting pre-training bias scores from post-training biases scores *across* training conditions. The analytical strategy from experiment 1 was applied.

3.2 Results

3.2.1 Group characteristics

Mean age, $F(1, 36)=1.36$, gender ratio, $\chi^2(1) = .85$, $p = .36$, $p=.25$, BDI-II, $F(1,36)=1.50$, $p=.23$, and STAI-T, $F<1$, $p=.38$, scores were not significantly different between training conditions (see Table 1).

3.2.2 Attention Training Effects

Table 3 presents the RT data. Analysis yielded a main effect of Time, $F(1, 36)=6.17$, $p=.02$, with faster RTs at post-training, $M=520$ ($SD=48$), than at pre-training assessment, $M=534$ ($SD=50$). The main effect of Condition, $F(1, 36)=7.31$, $p=.01$, showed that RTs in the positive condition were faster, $M=507$ ($SD=43$), than in the negative condition, $M=547$ ($SD=54$). There was no effect of Trial Type, $F(1,36)=2.15$, $p=.15$, and also all interaction-effects were non-significant (F's<1.10).

3.2.3 Transfer to Interpretation Bias

As in experiment 1, there was substantial variability in attention bias acquisition scores (across conditions: $M=1.77$, $SD=25.28$, range: -49.41 – 54.51; see Table 3 for within condition statistics) warranting analysis of transfer of training at the individual bias acquisition level across conditions ($N=38$). Regression analysis showed that neither pre-training attention bias scores, $\beta=.06$, $p=.77$, nor individual bias acquisition scores, $\beta=.12$, $p=.58$, predicted the change in interpretation bias, $F<1$, $p=.85$, $R^2=1.00\%$, VIF=1.62, T=.62.

3.3 Discussion

The ABM procedure did not induce a positive or negative attention bias and pre-training attention bias as well as individual bias acquisition scores were also not related to interpretation bias. In an attempt to optimize the attention training, the procedure in experiment 2b presented emotional facial expressions to elicit stronger emotional reactions compared to verbal stimuli (Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013), and included longer stimulus presentation durations to allow longer elaboration on the stimuli presented (Mogg & Bradley, 2005).

4. Experiment 2b

4.1 Methods

4.1.1 Design Overview

The procedure of experiment 2b was identical to experiment 2a.

4.1.2 Participants

Undergraduate students with minimal depression levels (BDI-II scores < 14; for criteria see Beck et al., 1996; Van der Does, 2002) completed to the positive (n=20) or negative training (n=19). All participants provided informed consent and received course credits or 8 euro.

4.1.3 Tasks and Measures

Attention training. The ABM task from experiment 2a was modified such that after fixation two face expressions appeared at the left and right side from fixation for either 750 ms or 1000 ms (to test the effect of elaboration time). Within trials, the face pairs depicted a happy and a sad expression from the same actor or two neutral expressions from different actors. The horizontal distance between the center of the pictures was 12.37° (picture size 9.33° × 9.33°). After offset, a probe (an E or F) prompted participants to identify the letter by pressing the corresponding button. The next trial started 500 ms after a response was recorded.

Methodological features of the ABM procedure were identical to experiment 1. An equal number of trials presented the stimuli for 750 ms and 1000 ms in each phase.

Stimuli. Face expressions were drawn from the Karolinska Directed Emotional Faces database (Goeleven, De Raedt, Leyman, & Verschuere, 2008). Based on the hit rates (> 80%), intensity, arousal ratings (evaluated on 9-point rating scales), and identity (same actor for happy and sad faces), 24 happy (intensity: M=6.39, SD=1.64; arousal: M=3.85, SD=1.98), 24 sad (intensity: M=6.14, SD=1.66; arousal: M=3.67, SD=1.76), and 18 neutral (intensity: M=5.11, SD=2.17; arousal: M=2.51, SD=1.47) faces were selected.

Transfer task. The SST assessed interpretation bias. Two different version of each 20 items were used as pre and post-training assessment. Participants received 2.5 minutes to complete the task and a cognitive load procedure was applied (see experiment 2a).

Questionnaires. Self-report measures were identical to experiment 1 and 2a.

4.1.4 Data Preparation and Analytical Strategy

Errors, RTs faster than 150 ms and slower than 1500 ms, as well as individual outliers (i.e., ±3 SD from M) were removed from the pre- and post-training data. All participants performed satisfactory on digit trials and were included. Analyses were ran on 96% of the data. The analytical strategy was identical to experiment 2a.

4.2 Results

4.2.1 Group characteristics

Mean age, $F<1$, $p=.41$, gender ratio, $\chi^2(1) = .21$, $p = .65$, BDI-II, $F<1$, $p=.44$, and STAI-T, $F(1,37)=1.20$, $p=.28$, scores did not differ between training conditions (see Table 1).

4.2.2 Attention Training Effects

The RT data is presented in Table 3. Analysis on RTs for trials presenting stimuli for 750 ms revealed no significant main or interaction effects of Time × Condition, Trial Type × Condition, or Time × Trial Type. Also the crucial effect of Time × Trial Type × Condition was not significant (all *F*'s<2). The analysis on RTs for trials with 1000 ms durations yielded no effects of Time, $F<1$, Trial Type, $F<1$, or Condition, $F(1,37)=2.97$, $p=.09$. The interaction-effects of Time × Condition, $F(1,37)=2.65$, $p=.11$, Trial Type × Condition, Time × Trial Type, and Time × Trial Type × Condition were also not significant, *F*'s <1.

4.2.3 Transfer to Interpretation Bias

Individual differences in transfer were examined across conditions ($N=39$) given the considerable variability in attention bias acquisition (across conditions: for 750 ms duration: $M=2.00$, $SD=52.13$, range: -127.25 – 146.63; for 1000 ms duration: $M=4.76$, $SD=50.42$, range: -131.38 – 121.25; see also Table 3 for within condition statistics). For 750 ms presentation durations, regression analysis on change scores of interpretation bias ($F<1$, $p=.67$, $R^2=2.20\%$, VIF=1.59, T=.63) revealed no predictive effects of pre-training attention bias, $\beta=-.17$, $p=.41$, nor individual bias acquisition scores, $\beta=-.16$, $p=.45$. For 1000 ms presentation durations, regression analysis showed that not pre-training attention bias, $\beta=-.18$, $p=.35$, but individual bias acquisition scores, $\beta=-.46$, $p<.05$ predicted the change in interpretation bias. However, the model with the two predictors had no significant fit: $F(2, 36)=3.05$, $p=.06$, $R^2=14.5\%$, VIF=1.60, T=.63.

4.3 Discussion

The dot-probe training induced neither a positive nor a negative attention bias. Again, pre-training attention bias scores and individual differences in attention bias acquisition were not related to performance on the interpretation transfer task.

5. General Discussion

Three experiments investigated transfer effects of single-session dot-probe attention training procedures to manipulate emotional biases in attention allocation. In contrast to prior research reporting effective modification of attention through dot-probe training in healthy samples (Hakamata et al., 2010; Hallion & Ruscio, 2011; Mogoase et al., 2014), we found – across three studies– no evidence that dot-probe ABM can induce or reduce attention biases via a single-session training. Although the applied training procedure closely resembled procedures that have effectively implemented ABM (Amir et al., 2008; Van Bockstaele et al., 2011), we did not find changes in attention bias at the training condition level in response to training toward negative, positive, or away from negative with various stimulus materials (i.e., emotional scenes, words, facial expressions) and stimulus presentation durations (500ms, 750ms, 1000ms). Thus, the present findings add to recent research that did not replicate successful ABM delivery (e.g., Boettcher et al., 2013; Carlbring et al., 2012; Rapee et al., 2013).

When inspecting individual differences in bias acquisition, we consistently observed a large inter-individual variability both within and across training conditions indicating that attention bias changed in accordance to the contingency of the dot-probe procedure in a subset of the trained individuals, in the conducted experiments varying from 42% to 65%. Analogous to studies indicating that such individual differences predict changes in anxiety (Clarke et al., 2012; Clarke et al., 2008), we tested whether individual differences the natural propensity to attend to emotional material (i.e., pre-training attention bias scores) and the propensity to modify the natural attentional pattern (i.e., individual bias acquisition scores) were related to individual differences in performance on the transfer tasks. We found no evidence for transfer of attention training at the individual differences level of analysis. Individual bias acquisition scores were not related to congruent biases on an affective task-switching task presenting new, non-trained stimuli. This finding seems to be in contrast with prior studies reporting transfer from dot-probe training to new stimuli presented in a spatial cueing (attention) task (Amir et al., 2009; Amir et al., 2008; Heeren et al., 2011). Furthermore, we found no evidence for transfer of individual training effects to interpretation bias. Individual bias acquisition scores were not related to performance on an interpretation test presenting trained (experiment 2a) or non-trained (experiment 2b) stimuli. This is surprising in light of prior research showing that interpretation mediates the relation between attention and memory bias (Everaert et al., 2014; Everaert et al., 2013). Moreover, the pre-training attention bias scores did not predict affective task-switching costs nor the change in interpretation bias. This suggests that an individual’s natural tendency to allocate attention to emotional material, measured before attention training, is not related to performance on transfer tasks tapping into cognitive processes related to attention.

What factors may explain the variability in ABM response and modulate transfer? Effective ABM delivery may depend on attentional control (Eysenck, Derakshan, Santos, & Calvo, 2007), that is a person's ability to exert top down control to focus attention on stimuli appearing at the probe's location and to inhibit attention on stimuli at the opposite location. Individuals with better attentional control may benefit more from ABM training which might enhance transfer of training. The role of top down attentional control in bottom up (dot-probe) ABM and how this alters transfer requires future investigation. A second factor that could moderate training and transfer are emotion regulation strategies. Such strategies (e.g., reappraisal, rumination) do not only involve attention toward information that matches one's concerns, but also cognitive processes to which ABM might transfer, in that way moderating (transfer of) training. Interestingly, research found that high ruminators trained to attend toward positive material showed a stronger positive bias after training (Arditte & Joormann, 2014), and observed a close relation between rumination and emotional biases in interpretation (Mor, Hertel, Ngo, Shachar, & Redak, 2014). Future studies may consider trait differences in emotion regulation when evaluating ABM training and transfer effects. A last factor concerns the limited reliability of the dot-probe task to measure attention bias, as such jeopardizing detection of training and transfer (Salemink, van den Hout, & Kindt, 2007; Schmukle, 2005). Particular task features (e.g., intra-individual variability in voluntary responses) and the nature of attention (e.g., flexible prioritizing on a trial-by-trial basis depending on thoughts that come to mind) could explain the low reliability. Its causes need to be identified to optimize future task designs.

Several limitations of the experiments conducted should be acknowledged. A first limitation is the lack of effective ABM implementation at the condition level. Although examining transfer via individual bias acquisition scores is informative, transfer of ABM may need to be retested after effective ABM delivery at the condition level. A second limitation is the measurement of affective task-switching after the ABM procedure in experiment 1. Although this avoids adverse consequences of long experimental sessions, we cannot rule out that there were pre-existing differences between training conditions. Measuring switching ability before and after training would enable a more rigorous test of transfer from ABM to this process. Another limitation concerns the order of cognitive tasks after training delivery. In all experiments, participants completed a transfer task after post-training bias assessment which could have reduced ABM effects on the transfer task. However, proof of change in attention bias and transfer is essential to draw conclusions on training effects and how they transfer (see also Van Bockstaele et al., 2011). Of final note, the limited range of psychopathology may have obscured training and transfer effects. Studies by Blaut et al. (2013) and Arditte and Joormann (2014) observed training or transfer at higher levels of depression or rumination. The restricted range of affective symptoms in the current experiments limits exploration of such moderation effects.

6. Conclusion

Three experiments provide no evidence for single-session dot-probe ABM to effectively manipulate attention biases toward negative, away from negative, or toward positive stimuli at the training condition level. The large individual variability in attention bias acquisition was not related to individual differences in performance on transfer tasks of flexible affective processing and interpretation. Future research may need to investigate factors that moderate attentional plasticity in response to dot-probe ABM to optimize conditions for effective implementation and transfer of training.

Author's note

Experiment 1 was designed by J.E., C.M., D.D., E.H.W.K., and C.M. recruited participants and performed the data-analysis. Experiments 2a and 2b were designed by J.E., E.H.W.K, and J.E. recruited participants and performed the statistical analyses. J.E. and C.M. contributed equally to the writing of this manuscript.

Footnotes

[1] The affective task-switching task presented an equal number of repetition and switch trials across the training conditions. There were 121.31 (SD=7.98) switch and 118.68 (7.89) repetition trials, $t(72)=1.42$, $p=.16$.

[2] IAPS pictures used. Positive animate images: 1600, 1920, 8380, 2340, 2530, 1460, 5831, 2311, 8080, 1463, 1590, 1811, 7502, 2650, 8461. Positive inanimate images: 5600, 5700, 5260, 5270, 5780, 7430, 7350, 7200, 5480, 7470, 7580, 7270, 8170, 8501, 8510. Negative animate images: 1111, 1270, 2120, 9530, 6561, 9430, 2691, 9041, 6010, 6242, 8480, 6211, 2900, 2753, 1280. Negative inanimate images: 9300, 6020, 9622, 6610, 9390, 9001, 9000, 9320, 9008, 9110, 9373, 9912, 9470, 9440, 9911.

[3] RTs on switch trials (M=1059, SD=198) were significantly higher than RTs on repetition trials ($M=911$, $SD=157$), confirming task-switching costs, $t(72)=15.31$, $p<.01$. Moreover, the task-switching costs on inconsistent trials ($M=220$, $SD=119$) were larger than on consistent trials ($M=102$, $SD=100$), $t(72)=6.75$, $p<.01$.

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Table 1.

Sample characteristics Experiment 1, 2a, and 2b

	Experiment 1			Experiment 2a		Experiment 2b	
Variable	Neutral	Negative	No-training	Positive	Negative	Positive	Negative
Gender ratio (f/m)	20/5		21/5	10/8	14/6	18/2	16/1
Age	20.70		21.76	18.78	19.85	19.10	18.53
	(1.78)		(3.38)	(1.86)	(3.47)	(2.45)	(1.55)
BDI-II	8.92	5.78	9.80	7.06	8.50	5.40	6.32
	(8.61)	(5.35)	(7.11)	(3.51)	(3.73)	(3.98)	(3.37)
STAI-T	41.16	38.17	43.76	36.72	38.85	34.25	36.79
	(10.89)	(9.14)	(11.48)	(5.54)	(8.73)	(6.81)	(7.64)

Note1. Standard deviations are shown between parentheses.

Note2.Gender data for the negative training condition and age data for the no-training condition were missing in Experiment 1

Table 2.

Attention training data for Experiment 1

	Condition		
Variable	Neutral	Negative	No-training
Pre-training			
Congruent	587 (86)	545 (54)	570 (82)
Incongruent	584 (77)	546 (58)	566 (84)
Post-training			
Congruent	559 (73)	533 (61)	523 (70)
Incongruent	553 (71)	536 (66)	516 (75)
ABA	2 (29)	0 (36)	2 (33)
TCC	44%	60%	40%*

Note1. Means are displayed with standard deviations between parentheses. *Note2*. ABA = attention bias acquisition score. *Note3*.Training congruent change (TCC) refers to the percentage of individuals who showed a change in attentional bias score congruent with the delivered training. In the no-training group, 40% exhibited a bias away from threat and the remaining 60% showed an attention bias toward threat compared with baseline.

Table 3.

Attention training and interpretation data for Experiment 2a and 2b

	Experiment 2a		Experiment 2b			
	Positive	Negative	Positive		Negative	
Variable	500ms	500ms	750ms	1000ms	750ms	1000ms
Pre-training						
Congruent	515 (45)	556 (58)	604 (91)	588 (81)	655 (106)	653 (108)
Incongruent	507 (43)	556 (52)	599 (90)	584 (93)	659 (105)	645 (116)
SST	25 (16)	27 (19)	19 (15)		19 (12)	
Post-training						
Congruent	504 (40)	537 (57)	600 (62)	594 (63)	618 (81)	614 (73)
Incongruent	501 (42)	536 (49)	602 (68)	598 (61)	618 (78)	607 (70)
SST	24 (14)	23 (16)	14 (14)		18.64 (15)	
ABA	4 (20)	-1 (30)	8 (54)	8 (50)	-4 (50)	1 (52)
TCC	50%	55%	55%	65%	42%	47%

Note1. Means are displayed with standard deviations between parentheses. *Note2*. ABA = attention bias acquisition score. *Note3*.Training congruent change (TCC) refers to the percentage of individuals who exhibit a change in attentional bias score congruent with the delivered training.