

**School of Psychology**

**An Investigation in Attention Bias Modification Training:  
Attention Bias Assessment, Acquisition and Change with the Dot-  
Probe Task**

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of  
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**Declaration**

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

**Human Ethics**

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number #HRE2016-0488

Signature:

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### Abstract

**Background:** Our environment provides more stimulation than we can process at any one time. Attentional mechanisms exist to help us select information that is important or salient. Selective attention, however, becomes non-adaptive when these attentional mechanisms continuously over-select negative information in the environment. This over-selection of negative information is known as a negative attention bias. In extreme manifestations, negative attention bias has been associated with a wide range of psychopathology, anxiety in particular. The dot-probe task, designed to assess selective attention, is used to quantify the existence and magnitude of a negative attention bias. In this task, participants react to a neutral probe that either replaces a negative or a neutral stimulus, both being presented on a screen simultaneously. It is assumed that for those who have a negative attention bias, attention is captured by negative stimuli. These individuals respond quicker to probes presented in the same location as the negative stimuli, compared to probes presented in the same location as the neutral stimuli. Recently, evidence has been accumulated showing that attention bias has a causal relation with psychopathology. Some studies have shown that emotional vulnerability related to psychopathology decreased when attention bias is manipulated away from negative information. The manipulation of selective attention is achieved by providing a predictable stimulus-probe contingency, whereby the probe is always presented in the same location as the previously presented neutral stimulus. However, most studies have been unsuccessful in achieving this attention bias change. Understanding the mechanisms responsible for a successful attention bias change through the use of the dot-probe task in the scientific community still seems to be lacking. There is, therefore, a need to improve the efficacy of attention bias modification (ABM).

#### **Study 1a – Attention Bias Modification with Non-emotional Stimuli:**

Three experiments were conducted to increase general understanding of the stimulus-probe associative learning mechanism in the dot-probe task. Non-emotional stimuli (shapes) were used to control for the interference of individual differences that come with responding to emotional stimuli. The design consisted of two training phases with predictive stimulus-probe contingencies (95% congruency), in which the stimulus-probe association changed to a reversed contingency in the second training session. Assessment phases with non-predictive stimulus-probe contingencies (50% congruency) were employed after each training phase and contingency awareness

was measured with a self-report measure after each experiment. The existence and magnitude of an attention bias was assessed in each phase by calculating a bias index score where the reaction times (RTs) obtained in the congruent trials were subtracted from the RTs obtained in the incongruent trials. Firstly, it became evident that, compared to a ‘no training’ control condition, attention bias was only induced in the reversed training, never in the initial training. This finding was consistent with varying difficulty levels of the dot-probe task, both with and without a baseline assessment. The latter finding ruled out the pre-exposure effect, which hypothesised that the lack of attention bias acquisition in the first training phase may have been instigated by pre-exposing participants to a non-predictive contingency wherein participants learned that the stimuli were uninformative. Secondly, the attention bias acquired in the second training phase was never evident in the assessment post-training. Lastly, only those aware of a stimulus-probe contingency showed evidence of attention bias acquisition in the second training phase.

#### **Study 1b – Attention Bias Modification with Emotional Stimuli:**

Two experiments with emotional stimuli (angry and neutral faces) were conducted to test whether the results found in the first three experiments could be replicated when emotion was included. In the first experiment, two training phases were employed. One training phase was employed in the second experiment in order to reduce cognitive load. Social anxiety was assessed in both experiments. State and trait anxiety as well as attention control of selectivity and inhibition were assessed in the second experiment, which were hypothesised to be predictors of attention bias acquisition and change. Anxiety was assessed pre-experiment through self-report, whereas attention control was assessed with an anti-saccade task that used non-emotional stimuli post-experiment. The results indicated that attention bias was not induced in either experiment and anxiety did not explain any variance of attention bias acquisition or change. Attention control of inhibition was associated with attention bias acquired within training. In particular, participants in the ‘attend-neutral’ training condition who possessed a higher control of attentional inhibition showed attention bias acquisition away from negative information during training. Participants in the same condition with a lower control of attentional inhibition did not acquire an attention bias away from negative information during training.

**Study 2 – Attentional Engagement and Disengagement Bias Change:** The engagement and disengagement processes are mechanisms that locate and relocate

selective attention, respectively. A bias in either of these mechanisms can be measured with the attention process assessment (APA) task. This experiment tested whether participants' attentional engagement and disengagement process changed pre- to post-training after completing either the dot-probe training task or a novel gamified ABM task (the emotion-in-motion task). Similar to the previous experiments, neutral and angry faces were used as stimuli. The results showed that only the dot-probe task induced a change in the attentional bias pre- to post-ABM. It was noted that participants had a difficulty disengaging from angry faces after completing the dot-probe training, irrespective of the training condition ('attend-neutral' vs 'attend-angry').

**Discussion:** Study 1 provided insights into the stimulus-probe associative learning mechanism of the dot-probe task with non-emotional and emotional stimuli. According to the findings, the assumption that the participants attend to a certain stimulus before the probe appears to be incorrect. This was supported by the findings of the first three experiments, suggesting that the contingency was only learned by those who reported that they were aware of a stimulus-probe association. Moreover, it would be incorrect to assume that an assessment task post-training captures the attention bias acquired within training. Other ways of assessing attention bias change needed to be considered. Furthermore, higher levels of attention control of inhibition were associated with successful attention bias acquisition assessed within training. Further research into the direction of this effect is recommended. It is possible that the attentional control of inhibition is an individual trait which predicts successful attention bias acquisition. However, it is also possible that the ABM training strengthened the attention control of inhibition, which resulted in successful attention bias acquisition. The main limitation of Study 1 involved the assessment of contingency awareness. An immediate or online assessment of contingency awareness would have increased the validity of the measure and provided more insights into its role in ABM. It was found in Study 2 that the attentional disengagement process was changed pre- to post-ABM with the dot-probe task, not with the emotion-in-motion gamified task. This change in attention bias occurred irrespective of training direction, such that participants trained to attend to angry as well as participants trained to attend to neutral faces showed greater difficulty disengaging from angry faces post-, compared to pre-dot-probe training. A limitation of Study 2 arose from the failure of randomisation. Biased attentional processes were

only found at baseline in participants allocated to complete the ‘attend-neutral’ training with the dot-probe task. To conclude, future recommendations derived from findings of both studies are discussed. Particularly, studies are recommended to test the efficacy of ABM procedures that combine bottom-up and top-down approaches, as solely providing bottom-up stimulus-probe associations may not be sufficient to modify attention bias. Implications drawn from this research further suggested that an attention bias change theory needs to be developed that addresses the necessary conditions and processes responsible for a reliably attention bias change.

## Chapter 1

### Introduction

#### **Bias in Selective Attention**

The preference to selectively attend to negative over neutral stimuli in the environment has been established as critical in the maintenance and aetiology of multiple disorders (Aspen, Darcy, & Lock, 2013; Duque & Vázquez, 2015; Schoth, Nunes, & Lioffi, 2012; Wabnitz, Martens, & Neuner, 2016). This preference is known as a negative attention bias. Selective attention is the central concept of attention bias theories, where in essence, the attention system selects certain items from large amounts of inputs that are present in the environment. However, there is still debate as to how the attentional system selects items to attend to.

#### **Selection Theories of Attention**

The earliest and best known theory of selective attention is the *filter theory* proposed by (Broadbent, 1958). He introduced the idea of early selection, where the selection of stimuli occurs early in the stream of processing. He theorised that the attention system filters out input stimuli based on simple physical attributes before they come into awareness. Opposing Broadbent's early selection theory were theorists who advocated *late selection theories*, notably Deutsch and Deutsch (1963), Norman (1968), and Mackay (1973). They theorised that the attention system had no capacity limitations and all recognised stimuli are processed. Furthermore, they stated that one cannot decide what to recognise and inputs are processed beyond cognitive control. The selection of stimuli that are attended to and come into awareness occurs later in the process, after analysis has occurred. This selection is limited in its capacity.

Between the two extreme views of early and late selection, other intermediate views have also emerged. One of them is the *attenuated model of processing* proposed by Treisman (1960). She stated that the selection filter (a) can be allocated to different input channels; (b) has limited capacity; and (c) is to a degree controlled by the individual. Another intermediate view is the *perceptual load theory* (Navon & Gopher, 1979). They proposed that selection will operate early when the load on perception is high and operate late when the load on perception is low. Yet another theory is the *automatic/controlled parallel theory* of selective attention proposed by Schneider and Shiffrin (1977). This theory assumes that there are two parallel processes of attention. One is a fast and automatic process that requires little effort,

while the other is a slow and controlled process that requires effortful training to develop. These theories are the foundations of multiple attention theories that have been developed over the years to explain the relation between attention and emotion.

### **Theories on Attention and Emotion**

At first, cognitive processes (i.e., attention) and emotional processes seem to be fundamentally different, and traditionally, it was common for researchers to treat them as distinct. Nevertheless, at present, it is known that these two phenomena are strongly interlinked (for review see: Shackman & Lapate, 2017). Theories of selective attention that account for the link between attention and emotion add a simple assumption to selection theories. This assumption is that emotional stimuli are more salient and that high-intensity emotional information is prioritised to be processed by the attentional system (Williams, Watts, MacLeod, & Mathews, 1988). These theories generally do not express how emotional stimuli become more salient as they often lean on biological theories (Öhman, 1993; Öhman & Soares, 1994). These biological theories state that humans have learned through evolution to pay attention to stimuli that carry high emotions like a dangerous animal that elicits fear.

In contrast, the classic *feature integration theory of attention* (Treisman & Gelade, 1980) explains how certain perceptual dimensions (i.e., colour and orientation), consisting of features (i.e., blue and horizontal) are processed automatically and prior to the selection of attention. This theory hypothesises that emotional stimuli belong to another perceptual dimension with features that capture attention from the visual environment. Another approach, and currently more preferred by researchers than the feature integration theory, is the *biased competition approach* (e.g., Buehlmann & Deco, 2008; Duncan, 2006). The biased competition approach is based on the assumption that our capacity is limited and stimuli compete to enter our visual attention processes. This competition is biased, either top-down (preferred stimuli match the task requirements, the environmental context, past experiences or prior knowledge) or bottom-up (preferred stimuli are more salient or higher in emotion intensity).

### **Theories on Bias in Selective Attention and Psychopathology**

Extrapolating from the attention and emotion accounts, theorists tried to explain the negative attention bias found associated with psychopathology. Two theories provided the foundations of recent ideas regarding the link between attention and psychopathology. The first was the *negative dysfunctional schemata theory*

proposed by Beck (1979). He proposed that sets of related beliefs and attitudes about the self, the world and the future (i.e., schemas) bias information processing. According to this view, negative dysfunctional schemas, found in disordered individuals, are the core of biased attention processing of negative and threatening information over neutral information. Later, Beck and Clark (1997) proposed a *three-stage schema-based model of information processing* in anxiety, which theorises that anxious individuals have automatic threat registration that leads to a primal threat mode. This mode consists of automatic, and strategic schema-driven process, these are primary appraisal, and vigilance for threat. These processes interact with a secondary elaboration stage that either enhances or reduces anxiety.

The second theory was the *associative-network theory* of Bower (1981; 1987), which postulated the existence of distinct emotional nodes, placed among nodes that correspond to persons' ideas, concepts, themes and memory of events. Together these nodes form an associative network. The theory hypothesised a two-way association between the emotional nodes and the other nodes, for instance a memory of an event activates the associated emotion and a certain emotion can activate a memory of the associated event. According to this view, disordered individuals have stronger links between negative emotional nodes and other representational nodes, compared to healthy individuals.

Building on these foundations, research has described in more detail how the link between attention and psychopathology can be best understood. Most experimental cognitive research that investigated the presence of attention bias in psychopathology has focused on anxiety disorders, as anxiety disorders are one of the most common forms of psychopathology. Therefore, the four most influential views with empirical support that theorise a link between attention and anxiety are described here. These are the *two-stage theory* (Williams et al., 1988), the *cognitive motivational analysis* (Mogg & Bradley, 1998), the *attention control theory* (Eysenck, Derakshan, Santos, & Calvo, 2007), and the *competition activation network* (Mathews & Mackintosh, 1998).

### **Two-Stage Theory**

Williams et al. (1988) proposed a two-stage model, which consists of a pre-attentive stage that takes place both before the attentive and elaboration phases where the representation of the stimulus will be produced. In this pre-attentive stage, the

affective decision mechanism judges the affective salience of an item (e.g., threat value) and all meanings of an item are activated. Then, a dominant meaning is selected and alternative interpretations are rejected by the resource allocation mechanism. On the basis of this decision, priorities for subsequent processing are determined, resources are either oriented towards that stimulus, or away from the source of the stimulus. Williams et al. (1988) concluded that people with high state anxiety have a biased affective decision mechanism in the pre-attentive stage, as they automatically select stimuli that are more threatening (hyper vigilant mode). Individuals high in trait anxiety have a bias in the resource allocation mechanism in the subsequent elaboration stage: they orient towards threatening stimuli compared to people with low trait anxiety who shift attention away from threat.

### **Cognitive Motivational Analysis**

Mogg and Bradley (1998) proposed that a motivational system mediates the cognitive and behavioural responses to emotionally salient stimuli. This motivational system contains two conceptually distinct systems, namely the emotional valence evaluation and goal engagement systems. The valence evaluation system is responsible for assessing the threat value of stimuli, output from this system feeds into the goal engagement system, which in turn determines the allocation of resources for cognitive processing resources towards the threat. Then, the goal engagement system either disregards it, and further inhibits processing, or continues to focus processing on current goals when labelled as threatening. Within this framework, each primary emotional stage is associated with its own cognitive mode and response tendencies. The valence evaluation of a stimulus can either be positive, negative or neutral, and the goal engagement can either result in disengaging from or engaging with the stimulus. This view states that anxious individuals continuously scan the environment for threats and possible danger because threatening stimuli are modulated by a negative valence and the external goal is to engage, as they anticipate possible danger.

### **Attention Control Theory**

The attention control theory proposed by Eysenck et al. (2007) states that attentional control is impaired in presence of a threat. As a result, a reduction in performance on cognitive tasks is expected, especially in high anxious individuals, who experience more threat responding than low anxious individuals do. The theory

assumes that threat to a current goal causes attention to be allocated to detecting its source and to establish a proper respond to that threat. Threat responding is further operationalised through three functions; these are inhibition (the use of attentional control to resist disruption or interference from task-irrelevant stimuli or responses), shifting (the use of attentional control to adapt and switch attentional focus) and updating (the use of attentional control to update and monitor working memory). According to the attention control theory, high anxious individuals have greater issues controlling threat responding as they have impaired control over the attentional inhibiting, shifting and updating functions compared to low anxious individuals. In addition, the theory acknowledges two attentional control pathways to which the threat can be perceived, one is stimulus-driven and uses bottom-up control of attention (i.e., detecting external threat or salient stimuli from the environment), the other is goal-directed and uses a top-down control of attention (i.e., detecting an event that threatens expectation, knowledge or current goals).

### **Competition Activation Network**

The theory of focus in this research project is the *competition activation network* developed by Mathews and Mackintosh (1998). They argued against a voluntary monitoring system that detects threatening stimuli in anxious individuals. They stated that anxious individuals find threatening stimuli distressing, and, therefore, try to ignore them. However, despite their efforts, their attention does capture threatening stimuli faster than other stimuli in the environment. The model proposed by Mathews and Mackintosh (1998) is based on the biased competition account where attention refers to various mechanisms that give priority to some representations over others when presented together. The authors assume that aspects of both stimuli (i.e., their attributes and meanings) are processed in parallel, prior to full awareness of their identity. Furthermore, the activation of the representations associated with potential danger are increased by input from a threat evaluation system that is strengthened by state anxiety. When two stimuli are competing for access to the response systems, each stimulus gains in activation, and simultaneously inhibits other representations drawing on common processing resources. This model supposes that this process of inhibition is more difficult in anxious compared to non-anxious individuals. The dot-probe task is the most common task used to assess whether a negative attention bias is present. The dot-probe task was designed by

MacLeod, Mathews, and Tata (1986) to measure whether stimuli compete for selective attention as proposed by the competition activation network.

### **The Development of the Dot-Probe Task as Assessment Tool of Attention bias**

The dot-probe task is a visual search paradigm where two stimuli are simultaneously presented on two areas of the screen. The stimuli used by MacLeod et al. (1986) consisted of 48 emotionally threatening words (24 socially threatening and 24 physically threatening) that were paired with 48 neutral words. The threatening and neutral words were matched on word length and frequency, so that there would be no differences in RTs due to these two aspects. The word pairs were presented vertically, such that one word was at the top, while the other was presented at the bottom of the screen. The 48 threat-neutral word pairs were mixed with 48 neutral-neutral word pairs, and presented for 500ms. Next, a probe that consisted of a dot either replaced the words at the top or bottom of the screen. The probe remained on the screen until a response was made. Participants were instructed to read the top word, out loud, and respond with a button click that corresponded to the location of the probe as soon as they saw the probe. Additionally, there were 192 neutral-neutral word pairs included as filler and these remained on the screen for 1 second (without any response needed). RTs to probes in these trials were discarded. Based on the 48 threat-neutral word pair trials, an attention bias is evident if participants showed a quicker response to probes in the same location as a threat word compared to probes in the same location as a neutral word.

MacLeod et al. (1986) showed that the task could differentiate responding to probes in threat and neutral locations between individuals clinically diagnosed with general anxiety disorder and non-anxious control participants. Individuals diagnosed with general anxiety disorder reported higher levels of state (feelings of anxiety at this moment) and trait anxiety (feelings of anxiety in general) as opposed to the control participants. Individuals diagnosed with general anxiety disorder responded quicker to probes if they were proximal to threatening words, irrespective of their location (i.e., attention bias towards threatening words). However, control participants showed quicker responding to probes that followed neutral words irrespective of their location (i.e., attention bias to avoiding threatening words). Subsequent studies used the same task on students 12 weeks before examination (low in state anxiety) and one week before examination (high in state anxiety; MacLeod & Mathews, 1988), and in current vs recovered patients with anxiety disorder (Mogg,

Mathews, & Eysenck, 1992). Both studies replicated the attention bias towards threat in anxious vs non-anxious individuals. Additionally, it was found that state anxiety did not determine the attention response to threat (MacLeod & Mathews, 1988), nor was there a difference between patients, who have recovered from anxiety or were currently patients (Mogg et al., 1992). The dot-probe task seemed to be a promising tool to assess attention bias towards threat in high-trait anxious individuals compared to low-trait anxious individuals.

One of the main advantages of the dot-probe task, as pointed out by MacLeod et al. (1986), was that participants responded in a neutral way (button pressing) to a neutral probe (a dot). Hence, the emotional content of the words was task irrelevant and this eliminated the possibility of response bias. Another advantage was that amongst participants, the task could distinguish between selective attention that was directed towards the location of threatening stimuli or directed away from threatening stimuli. Lastly, the task seemed to distinguish attention bias patterns between high and low-trait anxious individuals as predicted by theories on bias in selective attention bias and psychopathology. However, a limitation of the original dot-probe task was that a high number of trials were filler trials and half of the responses were discarded. Hence, the dot-probe task was time consuming without much data output. This was considered a disadvantage, particularly in clinical research where individuals with emotional disorders generally have difficulty sustaining attention over a long monotonous task (Mogg & Bradley, 1999b). A second limitation was that the nature of the task was a probe detection task. Selective attention did not need to shift to the probe in order to detect it in the peripheral field. These disadvantages indicate that the dot-probe task designed by MacLeod et al. (1986) may not measure spatial attention bias effectively.

The dot-probe task has been modified extensively since its development (Salemink, van den Hout, & Kindt, 2007). Mogg, Bradley, and Williams (1995) were the first to modify the dot-probe task and assessed attention bias in anxious, depressed and healthy controls. In their new version of the dot-probe task, participants were forced to respond on every trial. Participants indicated with button pressing whether the probe appeared in the top or bottom location of the screen. This modification changed the nature of the dot-probe task from a probe detection to a probe location discrimination task. Moreover, compared to the original dot-probe task, the possible interfering voice responses were excluded and no foil trials were

included. Furthermore, the exposure duration of the word pairs was either 500ms or 1000ms. Additionally, the word pairs were not only threatening, but also disorder relevant. That is, participants, either high in anxiety or depression, received anxiety- and depression-relevant negative-neutral word pairs. Finally, they also included positive-neutral word pairs, however, it was found that anxious and depressed individuals did not have an attention bias towards emotional words in general, rather towards negative words only. Furthermore, it was found that anxious and depressed individuals, compared to healthy controls showed a general attention bias towards negative words, and not only for the disorder relevant words as expected. This is in contrast with a more recent meta-analysis by Pergamin-Hight, Naim, Bakermans-Kranenburg, van Ijzendoorn, and Bar-Haim (2015). They found that the use of disorder relevant vs irrelevant stimuli yielded greater effect sizes when assessing the existence of a negative attention bias. The results of Mogg et al. (1995) may be explained by the large comorbidity between anxiety and depression in their sample. The advantage of the first modification of the original dot-probe task by Mogg et al. (1995) is that it decreased the load on participants by excluding numerous foil trials, and including a forced choice response, based on location of the probe.

A couple of years later, Mogg and Bradley (1999a) modified the dot-probe task once more, and tested whether it reliably distinguished differential selective attention processes in a clinical sample of generalised anxious individuals. This time, instead of using word stimuli, pictorial stimuli of neutral, happy and angry faces were used. They argued that word stimuli were confounded with familiarity of the words, such that anxious individuals were possibly more familiar with threat than neutral words compared to non-anxious individuals. They further reasoned that facial stimuli were more naturalistic, ecologically valid, and salient than word stimuli. Other modifications of the dot-probe task were as follows: (a) a trial started with a fixation cross in the middle of the screen; (b) the stimuli were presented in the left and right location of the screen instead at the top and bottom; (c) the stimulus onset varied between 500ms and 1250ms between subjects; and (d) participants needed to respond to the type of the probe, either two dots orientated horizontally (like ‘. .’) or vertically (like ‘:’). The last modification changed the nature of the dot-probe task from a location discrimination to a probe discrimination task where selective attention needed to shift to the location of the probe to discriminate between the two probes. Using this modified dot-probe task, Mogg and Bradley (1999a) found that

individuals with general anxiety disorder, compared to healthy controls, showed an attentional bias to angry relative to neutral faces. Additionally, over the course of the task, those with general anxiety disorder also developed an attention bias towards happy relative to neutral faces. Compared to their previous study (Mogg et al., 1992), these results indicated that emotion in general seems to be more salient for individuals with general anxiety disorder compared to control participants. More importantly, the initiative to change the dot-probe task from a probe detection (i.e., is there a probe? MacLeod et al., 1986) to a probe discrimination task (i.e., what or where is the probe?; Mogg & Bradley, 1999a; Mogg et al., 1992) seemed to have had made a significant impact on the field. Since then, an increasing number of studies have begun using two types of probe discrimination tasks wherein participants either differentiate between two types of probes (type discrimination: “:” vs “..” or “E” vs “F” or “↑” vs “↓”) or where participants have to locate the probe (location discrimination: “left” vs “right” or “top” vs “bottom”; Salemink et al., 2007).

Currently, the dot-probe task is considered as the gold standard to measure the existence of attention bias in a range of psychopathology (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007). Bar-Haim et al. (2007) conducted a compelling meta-analysis of 172 studies and found that a threat-related attention bias was a robust phenomenon in participants with anxiety that was not evident in participants without anxiety (medium to large effect size of  $d = 0.41$ ). However, no consensus has been reached regarding what version of the dot-probe task assesses the existence of attention bias most reliably (Chapman, Devue, & Grimshaw, 2017). To summarise, the main differences in the versions of the dot-probe task employed are: (1) the type of task (probe detection vs probe discrimination [type vs location]); (2) stimulus types (words vs pictures); and (3) the SOAs (stimulus onset asynchrony between onset of the stimuli and onset of the probe): these vary between short (<100ms), medium (500ms) and long (>1000ms).

These differences in the dot-probe task versions and their impact on measuring attention bias have been tested in several experiments. The results show no significant difference between assessing attention bias with a probe location or probe type discrimination task (Mogg & Bradley, 1999b; Salemink et al., 2007). Furthermore, the meta-analysis conducted by Bar-Haim et al. (2007) concluded that attention bias towards threat was not moderated by the types of stimuli used. This finding was in line with other studies which found no difference between word and

pictorial stimuli (e.g., Freijy, Mullan, & Sharpe, 2014; Schmukle, 2005). On the other hand, other studies like Pishyar, Harris, and Menzies (2004) did find a difference in favour of pictorial stimuli. It is possible that the stimuli contents are more important than the types of stimuli used as shown by the recent meta-analysis conducted by (Pergamin-Hight et al., 2015). Lastly, Bar-Haim et al. (2007) found that different exposure times of the stimuli used in the dot-probe task (long vs short), did not result in different effect sizes in detecting an attention bias. However, a systematic review done by Bantini, Stevens, Gerlach, and Hermann (2016) found that a dot-probe task with SOAs of 500 to 600ms was preferred to dot-probe tasks with shorter (<175ms) or longer (>1000ms) SOAs.

There seems to be no consensus regarding what version of the dot-probe task is more successful in assessing the existence of a negative attention bias. However, Bar-Haim et al. (2007) found that the dot-probe task was effective in assessing attention bias in individuals with high levels of anxiety, both clinically diagnosed or self-reported. This finding holds true irrespective of anxiety type (i.e., state or trait anxiety) or anxiety disorder (i.e., general anxiety vs obsessive compulsion vs panic vs post-trauma vs social phobia vs simple phobia). Furthermore, the dot-probe task was successful in assessing a negative attention bias in children as well as adults. Together, these findings show that the dot-probe task seems to be an effective task for assessing attention bias related to psychopathology.

### **Reliability Concerns of the Dot-Probe Task**

Other researchers have disputed the validity and reliability of the dot-probe task (e.g., Chapman et al., 2017; Kappenman, Farrens, Luck, & Proudfit, 2014; Schmukle, 2005; Staugaard, 2009; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014). The dot-probe task has been compared to other attention bias measures and found low external validity. For example, the results from the dot-probe task were compared to the results of the electroencephalogram (EEG), which measures electrical activity in the brain. Participants performed the dot-probe task while wearing an EEG. Attention bias to threat was evident in the N2pc component of the event-related potential (ERP) waveform, which is linked to selective attention, however, not in the RTs of the dot-probe task (Kappenman et al., 2014; Kappenman, MacNamara, & Proudfit, 2015). This indicates low predictive validity of the dot-probe assessment task. Furthermore, Waechter et al. (2014) compared the reliability of attention bias measured with a dot-probe task and an eye-tracker device. The RTs

of the dot-probe task were compared to first fixation, viewing time over the first 1500ms, and viewing time over the total 5000ms. Waechter et al. (2014) found that attention bias to threat was reliably measured with an eye-tracker when using the total 5000ms viewing time.

In addition to poor external validity, there are issues of poor internal reliability (e.g., Schmukle, 2005). Low internal reliability scores arise from inconsistencies in RTs that do not follow the particular pattern inherent to negative attention bias (i.e., quicker responding to probes that follow the negative relative to neutral stimuli). This may suggest that the dot-probe task does not measure a negative attention bias. However, since different versions of the dot-probe task have been shown to be sensitive in assessing a negative attention bias in a sample of vulnerable individuals compared to healthy controls, it is possible that the construct itself is inconsistent over time. In other words, the assumption that attention bias is a stable construct may need to be reconsidered (Rodebaugh et al., 2016; Zvielli, Bernstein, & Koster, 2015). In addition, RTs vary within each participant and within each trial type. This variability increases substantially when these RTs are combined into a difference score. There are, however, ways of measuring attention bias with the dot-probe task which results in increased reliability (MacLeod & Grafton, 2017; MacLeod, Grafton, & Notebaert, 2019; Price, Brown, & Siegle, 2018).. For instance, MacLeod et al. (2019) have presented a new version of the conventional dot-probe task, where instead of one single probe, two probes are presented in both locations for 200ms. Participants are required to respond to the probe they saw, thereby providing data on which stimulus location attention was located at the moment of processing. This task enhanced the reliability scores, such that the internal reliability of the assessment task was 0.92 compared to 0.10 of the conventional dot-probe assessment task. The test-retest reliability was improved from 0.08 on the conventional dot-probe assessment task to 0.98 on the dual dot-probe assessment task.

Despite concerns regarding internal and external validity and reliability, the dot-probe task has gained popularity. It has been employed in a number of different psychopathologies to assess whether attention bias is also evident in other emotional and non-emotional disorders. Using the dot-probe task, evidence for attention bias toward psychopathology related stimuli over neutral stimuli was found in individuals with mood disorders (e.g., Peckham, McHugh, & Otto, 2013; Winer & Salem, 2016),

addictive behaviours (e.g., Yeomans, Javaherian, Tovey, & Stafford, 2005), eating disorders (e.g., Brooks, Prince, Stahl, Campbell, & Treasure, 2011), pain (e.g., Sun, Wang, & Luo, 2014; Todd, Sharpe, & Colagiuri, 2016), sleep disorders (e.g., Harris et al., 2015; Jansson-Fröjmark, Bermås, & Kjellén, 2013; MacMahon, Broomfield, & Espie, 2006), and schizophrenia (e.g., Jang, Park, Lee, Cho, & Choi, 2016). Since its development in 1986, the dot-probe task has taken deep roots across multiple areas of psychopathology as the gold standard for assessing attention bias.

### **The Dot-Probe Task and the Modification of Attention Bias**

After utilising the dot-probe task to establish that attention bias was related to psychopathology, researchers have attempted to establish whether a change in attention bias would also induce a change in psychopathology. MacLeod, Rutherford, Campbell, Ebsworthy, and Holker (2002) were the first to show that attention bias can be modified. They adapted the word dot-probe task of Mogg et al. (1992) such that it manipulated selective attention. Mid-trait anxious participants were trained to either attend to negative or neutral words. This was achieved by always placing the probe in the same location after the negative word (in the case of the ‘attend-negative’ condition) or always in the same location after the neutral word (in the case of the ‘attend-neutral’ condition). Furthermore, word pairs were either presented for a very short (20ms) or longer time (480ms). This was done to establish whether change of attention bias occurred at a conscious or pre-conscious level. The manipulation of selective attention was done in a total of 576 trials. Ninety-six of those trials were designated assessment trials. In the assessment trials the probe was presented in the same location, equally often following the negative and neutral words. Participants were required to make a discrimination judgement on the identity of the probe that consisted of either a single pixel or two adjacent pixels. Following the attention manipulation, participants were exposed to an anagram-based stress task, designed to elicit negative emotion. Emotion reactivity to this task was measured with two single-item scales, which assessed levels of anxiety and depression pre- to post-stressor task.

In the assessment trials, it was found that participants in the ‘attend-neutral’ condition reacted quicker to probes preceded by neutral words relative to the negative words. The opposite pattern was found for participants in the ‘attend-negative’ condition, this indicated that selective attention is malleable by employing predictive stimulus-probe contingencies in the attention training procedure with the

## AN INVESTIGATION INTO ATTENTION BIAS MODIFICATION

modified dot-probe task. Moreover, the change of attention bias was only significant when longer exposure times were used (480ms), not when shorter exposure times (20ms) were used. This finding suggests that attention bias is changed at a conscious level. For those who conducted the task with the longer exposure times, the stress-anagram task significantly increased the self-reported scores on the single-item anxiety and depression scales from pre- to post-stressor task. Participants in the ‘attend-neutral’ condition showed a trend for a smaller difference in the anxiety and depression scores pre- to post-stress induction compared to participants in the ‘attend-negative’ condition. This interaction was only marginally significant, and, therefore, the procedure was replicated by a second experiment that only used 500ms exposure times to increase power.

In the replication study, the interaction became significant. There was no increase in anxiety and depression scores from pre- to post-stress induction in participants belonging to the ‘attend-neutral’ condition. However, there was a significant increase in anxiety and depression scores from pre- to post-stress induction in participants belonging to the ‘attend-negative’ condition. MacLeod et al. (2002) concluded that selective attention can be reliably manipulated in an attention bias modification (ABM) paradigm when using a training version of the dot-probe task. Moreover, the change of attention bias occurred only at a conscious level (stimulus exposure of 500ms) rather than a pre-conscious level (stimulus exposure of 20ms). Furthermore, ABM did not have a direct effect on psychopathological symptoms, as participants in both conditions reported similar anxiety and depression levels directly after ABM. However, the difference in anxiety and depression as a result of a stress anagram task was significantly higher when selective attention was trained towards negative stimuli compared to neutral stimuli. These initial results supported the notion that attention bias does not only correlate with emotion vulnerability, attention bias and emotional vulnerability seem to be causally related.

This finding elicited an exponential growth in the number of studies and citations per year on ABM that used the dot-probe task. From zero studies and citations in 2000 to approximately 80 studies and 2000 citations per year in 2016 (Clarivate Analytics, 2018). This growth can be attributed to the positively framed and promising reviews written on the first studies that manipulated selective attention with a dot-probe task and measured the effect of ABM on anxiety symptoms (Bar-Haim, 2010; Beard, 2011). Furthermore, the reviews suggested that a negative

attention bias, in combination with stress induction, increases the levels of anxiety. However, it was also concluded that negative attention bias patterns can be altered through ABM, which in turn lowers stress reactivity. These promising conclusions were supported by the meta-analyses conducted by Hakamata et al. (2010) and Hallion and Ruscio (2011) who found that ABM had a significant medium effect on anxiety. Additionally, it was found that ABM had a smaller effect on healthy subjects ( $d = 0.48$ ; non-anxious:  $d = 0.36$ ; high-anxious:  $d = 0.62$ ) compared to patient samples ( $d = 0.78$ ) and that word stimuli seemed to be more effective ( $d = 1.29$ ) than face stimuli ( $d = 0.37$ ; Hakamata et al., 2010). Furthermore, a single session ( $g = 0.11$ ) seems to be less successful compared to multi-session ABM ( $g = 0.40$ ; Hallion & Ruscio, 2011). Overall, the dot-probe task seemed to be promising in manipulating attention bias, with a subsequent effect on psychopathology.

After 2016, the number of publications and citations started to drop for the first time (Clarivate Analytics, 2018). Meta-analyses conducted later on larger numbers of studies were more pessimistic about the effect of ABM on anxiety (Cristea, Kok, & Cuijpers, 2015; Heeren, Mogoșe, Philippot, & McNally, 2015; Mogoșe, David, & Koster, 2014). These concluded that ABM had a small effect on anxiety symptoms after a stressor, the effect was even smaller directly after ABM, which is in line with MacLeod et al. (2002). Moreover, this effect decreased significantly, to non-significant in Cristea et al. (2015) after controlling for publication bias. Cristea et al. (2015) even went as far as concluding that the effect of ABM is non-existent, and that the small positive effects found were merely driven by ‘experimenter effects’ (i.e., response bias and demand characteristics). It seems that the initial enthusiasm regarding ABM as a promising intervention for psychopathology has reduced. What remains is the lack of understanding on the mechanisms that underlie ABM and the need to explain why there is a lot of variance in the effect of the dot-probe training task on psychopathology symptoms and emotional vulnerability when ABM is implemented.

Grafton et al. (2017) as well as MacLeod and Clarke (2015) explained that this variance in effects of ABM on emotional reactivity is evident because past research did not always include a pre- and post-assessment of attention bias. That is, not all studies measured whether a change in attention bias occurred. Given that the reduction in emotion vulnerability seems to be dependent on a change in attention bias, no conclusion can be drawn about the efficacy of ABM when attention bias

change was not assessed. For instance, the conclusions of the meta-analysis conducted by Cristea et al. (2015) on ABM has been criticised by Grafton et al. (2017) for not controlling for successful attention bias change. The meta-analysis concluded that ABM has small effects on mental health problems and may not be clinically relevant after controlling for publication bias. However, when Grafton et al. (2017) re-analysed the studies that were part of the meta-analysis of Cristea et al. (2015) it was revealed that a change in attention bias predicted a change in emotion vulnerability. According to Grafton et al. (2017), studies successful in changing attention bias in ABM were also successful in changing emotional vulnerability, and studies unsuccessful in changing attention bias in ABM were also unsuccessful in changing emotion vulnerability. A limitation of Grafton et al. (2017), however, is that they did not calculate the possible influence of a publication bias.

Overall, over the course of the development of ABM research, the tone has changed quickly from investigating the causal relationship between selective attention and anxiety on a mechanistic level (MacLeod et al., 2002) to the effectiveness of ABM as a clinical intervention for anxiety disorders (e.g., Cristea et al., 2015). ABM began as an experimental paradigm with a strong theoretical background that manipulated selective attention to explain its influence on psychopathology. Since, research on ABM has exponentially grown in a relatively short time from a mechanistic level to a clinical intervention, where it was labelled as non-effective (e.g., Cristea et al., 2015). In colloquial terms, people run before they can walk and this area of research needs to go back and explore mechanisms of effective walking before running is progressed again.

Generally, it appears that not everybody is successful in modifying attention bias when delivering the training procedure in the ABM paradigm. The importance of understanding factors that influence the attentional processes, which underlie the modification of negative attention bias, has been repeatedly addressed in literature (e.g., Heeren et al., 2015; Lowther & Newman, 2014; MacLeod & Clarke, 2015). In particular, Koster, Fox, and MacLeod (2009) stressed that the methodology to modify cognitive biases needs to be innovated and refined as well as that it is necessary to advance the understanding of the nature of these biases to guide the modification. Therefore, the processes that underlie a change in selective attention need to be understood before ABM is used as an intervention tool to change emotional reactivity related to psychopathology.

### **Overview of the Current Research Program**

According to MacLeod and Clarke (2015) two questions need to be addressed when researching ABM. The first question is of most importance here: whether an attentional training successfully elicits a change in selective attention. As described above, Clarke, Notebaert, and MacLeod (2014), as well as Grafton et al. (2017), critiqued the latest meta-analyses and reviews for not controlling for the establishment of attention bias change. It is of high importance that meta-analyses take into account a change in attention bias. Not all studies were successful in changing attention bias (i.e., Britton et al., 2013; Grey & Mathews, 2009) or measured whether successful attention bias happened due to ABM (i.e., Hirsch, Hayes, & Mathews, 2009; Schmidt, Richey, Buckner, & Timpano, 2009). Without this change in attention bias, the second question is not applicable: whether this change in attention bias also significantly modifies emotional reactivity. Therefore, this thesis will focus on the first question, and will not investigate the second question.

Before ABM can be implemented in clinical practice, it is necessary to conduct extensive research on processes that underlie attention bias change. This is the notion of evidence-based practice. Currently, basic research on the processes that underlie ABM is limited. The research reported in this thesis aims to develop a strong basic experimental foundation and create an in-depth understanding of how selective attention behaves in an ABM paradigm. By providing this foundation, current and future methods of ABM can develop with a stronger experimental background and with a better understanding of underlying processes and other factors that moderate attention bias change. In particular, the objective of this thesis is to better understand the processes that underlie selective attention change in the ABM paradigm by: (a) investigating how the main learning mechanisms of the dot-probe tasks influence selective attention when modifying attention bias in the ABM paradigm; and (b) investigating how attention processes, which possibly underlie attention bias, change when employing different training procedures in the ABM paradigm. The thesis will be structured into two studies, study one addresses point (a) with five experiments, whereas study two will address point (b) with one experiment.

### **Study 1: The Investigation into the Main Mechanism of the Dot-Probe Task**

The dot-probe task assesses and trains selective attention by using different stimulus-probe associations. By utilising a non-predictive stimulus-probe association, that is, each of the two stimuli presented on the screen are randomly and equally often associated with the probe location (50% congruency), the dot-probe task assesses whether participants prefer to attend to one of the two stimuli. By utilising a predictive stimulus-probe association, that is, one of the two stimuli is consistently associated with the probe location (100% congruency), the dot-probe task trains participants to selectively attend to the stimulus that predicts the location of the probe. During the training phase, it is assumed that participants learn the stimulus-probe association, hence, learn to attend to the predictive stimulus to increase their performance on the task.

A series of five experiments was conducted in order to test the best conditions to establish learning of the stimulus-probe associations employed in the dot-probe task. The main objective of these experiments was to create a template wherein the dot-probe task was successful in acquiring, changing, and assessing attention bias towards stimuli by changing the stimulus-probe contingencies. To enable the assessment of attention bias during training, a 95% congruency was used instead of a fully predictive contingency of a 100% congruency. Additionally, this allowed for testing transfer of attention bias from assessment to training and back to an assessment phase. To create a template, each experiment differed in its design to establish the impact of that change on participants' learning of the stimulus-probe contingencies. Design changes included variations in the experimental procedure (i.e., different contingency orders) or variations in dot-probe task parameters (i.e., different stimuli or probe durations).

Secondary to the main objective, individual differences in stimulus-probe associative learning within the dot-probe task were assessed. Aside from levels of emotional vulnerability related to psychopathology, levels of contingency awareness and attention control were assessed to enhance the understanding of differences found in contingency learning. There is some controversy about the role of contingency awareness and contingency learning (see for review: Lovibond & Shanks, 2002). Some studies indicate that awareness of contingency is necessary for

contingency learning (e.g., Purkis & Lipp, 2001). This idea is supported by the *strong single-process model of learning* (Brewer, 1974). Other studies, however, support the *weak single-process* or a *dual-process model* (Razran, 1955; Squire, 1992), wherein contingency awareness does not condition learning (e.g., Walther & Nagengast, 2006). The three models are displayed in Figure 1.

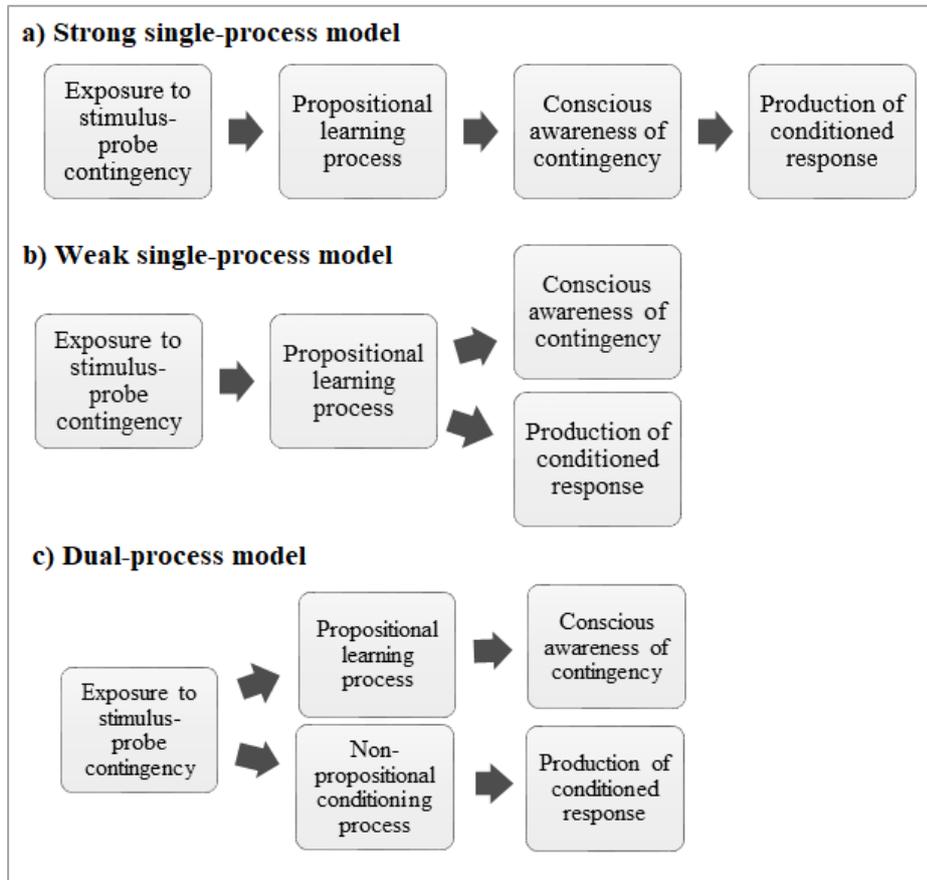


Figure 1. Process Models of the Relationship between Contingency Learning and Awareness. Adapted from Lovibond and Shanks (2002).

Contingency learning as used by Lovibond and Shanks (2002), in Pavlovian conditioning, can be used to inform stimulus-probe associative learning in the dot-probe task. In theory, someone can learn that there is a contingency without making any change in their selective attention. In Pavlovian learning, this would still be considered contingency learning. However, with respect to contingency learning in an ABM context, contingency learning is referred to as the change in selective attention in line with the training contingency. Therefore, contingency learning and attention bias change are considered as the same concept in this research project.

Studies that tested the involvement of contingency awareness in ABM have found that explicit instructions about the contingencies between the stimuli and the probes led to stronger learning of selective attention in ABM (Grafton, Mackintosh,

Vujic, & MacLeod, 2014; Krebs, Hirsch, & Mathews, 2010; Lazarov, Abend, Seidner, Pine, & Bar-Haim, 2017). However, the explicit instructions resulted in a decreased subsequent effect of ABM on emotional vulnerability (Grafton et al., 2014). Contingency awareness of the stimulus-probe association within the dot-probe task has not yet been investigated without giving explicit instructions. It may be that awareness of the stimulus-probe contingency in training needs to be acquired implicitly. Research into the role of acquired contingency awareness in the trainability of selective attention is currently lacking.

Attention control seems to be another important factor that is associated with the existence of attention bias and attention bias change. Attention control may be an important mechanism that controls the processes that underlie negative attention bias (Eysenck et al., 2007; Taylor, Cross, & Amir, 2016). Impaired or dysregulated attention control has shown to be an important factor in the maintenance and aetiology of disorders like depression (De Raedt & Koster, 2010) and anxiety (Basanovic, Notebaert, Grafton, Hirsch, & Clarke, 2017; Derryberry & Reed, 2002; Taylor et al., 2016). Poor attention control can consist of a number of impaired attention processes such as difficulty with concentrating and alertness (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Hertel & Rude, 1991), impaired switching of attention (Murphy et al., 1999; Rokke, Arnell, Koch, & Andrews, 2002; Taylor et al., 2016), poor attention engagement with, and poor disengagement from stimuli in the environment (Basanovic et al., 2017). Studies have shown that attention control may moderate the link between negative attention bias and emotional vulnerability. For instance, Taylor et al. (2016) found no direct link between attention bias and social anxiety. However, they found that at high levels of social anxiety there were individual differences in the shifting subscale of the Attention Control Scale, developed by Derryberry and Reed (2002). These individual differences were associated with differential patterns of attentional disengagement from threat stimuli. Explicitly, at high levels of attention control-shifting, high socially anxious individuals disengaged faster from threat-relevant compared to neutral social cues. In contrast, at low levels of attention control-shifting, those high in social anxiety disengaged slower from threat-relevant compared to neutral stimuli.

Other studies have further shown that individual differences in attention control and attention biases are associated mechanisms of attentional and emotional vulnerability (Basanovic et al., 2017; Everaert, Grahek, & Koster, 2017; Sanchez,

Everaert, De Putter, Mueller, & Koster, 2015). For instance, Everaert et al. (2017) found that deficient inhibitory control over negative stimuli was related to negative attention bias, which in turn predicted an interpretation bias as well as subsequently depressive symptoms. While, Basanovic et al. (2017) found that attention control predicts the magnitude of attention bias change. These findings converge with the possibility that individual differences in attention control are a boundary condition of attention bias patterns, therefore, the dot-probe task may not be effective in changing the attention bias for individuals with low attentional control.

Study 1 explored whether individual differences in contingency awareness and attention control influenced contingency learning, which would result in different patterns of attention bias acquisition, change, and assessment when using the dot-probe task.

### **Study 2: The Investigation into the Attentional Processes of Attention Bias**

In order to investigate the processes that underlie attention bias change, it is necessary to discuss the processes that underlie selective attention and negative attention bias. Posner (1980) proposed three processes that underlie selective attention: (1) attentional engagement with stimuli; (2) attentional disengagement from stimuli; and (3) attention shift from one to the other stimulus. Accordingly, either a negative attention bias can consist of an enhanced engagement with negative stimuli, difficulty disengaging from negative stimuli or both processes may be biased independently. That is, we are quicker to locate negative stimuli than neutral stimuli in our environment and/or we have more trouble relocating our selective attention away from negative stimuli than from neutral stimuli. Previous studies have acknowledged that negative attention bias is possibly related to one or more of these processes (see for review: Cisler & Koster, 2010).

Experimental investigators do not agree whether attention bias associated with heightened anxiety vulnerability is characterised by enhanced engagement of attention with negative stimuli, which supports the *single biased attentional engagement account*, or by impaired disengagement of attention from negative stimuli, which supports the *single biased attentional disengagement account* (Clarke, 2009). Methodological issues of disentangling the two attention bias types have limited this investigation. Because the traditional dot-probe task does not

differentiate between an engagement and disengagement bias, several researchers have attempted, however, failed to modify the dot-probe task with the aim to disentangle these two processes.

For instance, Koster, Crombez, Van Damme, Verschuere, and De Houwer (2004) developed the emotional spatial cueing (ESC) task, wherein two rectangles would be presented to the left and right side of the fixation cross for 500ms. After the initial fixation, one of the two rectangles located next to the fixation cross would function as a cue, as it became a coloured rectangle. The cue stayed on the screen for 200ms, a mask and finally the target followed this. The target was presented in either the same (labelled as valid trials: 75%) or opposite location (labelled as invalid trials: 25%) of the cue. The trials were either presented with a threat stimulus that consisted of a 100dBA white-noise burst (aversive but not painful) or a neutral tone at 71dBA. Both audio stimuli were presented after the target for 200ms each and were delivered through headphones (3:1 on valid and invalid trials). Participants were instructed to respond to the location of the target and were told that the cue was, in most cases, predictive of the target. Attention bias to threat was assessed by calculating the difference between RTs of validly, and invalidly cued trials with and without the aversive noise burst. In addition, the initial fixation of participants was ensured by including an extra task, that is, the fixation cross would sometimes be replaced by a number, which participants needed to say out loud. Furthermore, by making the predictivity of the cue explicit, it was assumed that participants' attention would have been in the location of the cue. The importance of initial fixation lies in the disentanglement of the attentional processes. Without it, it would be impossible to distinguish whether participants' attention engaged quicker or disengaged slower with a stimulus or whether the attention was already at a specific location of the screen.

The findings of the ESC task indicated that participants responded quicker on the validly compared to the invalidly cued trials. Furthermore, participants responded quicker on the valid trials that included the aversive noise burst compared to the valid trials that did not include the aversive noise burst. Therefore, it was concluded that attention was captured by threat (Koster, Crombez, Van Damme, et al., 2004; Koster, Crombez, Verschuere, & De Houwer, 2006; Salemink et al., 2007), which is evidence for the *single biased attentional engagement account*. It was a positive initiative to control for initial fixation, with the aim to disentangle attentional

engagement with, and disengagement from threatening stimuli. Nevertheless, by comparing RTs of trials with and without an additional threat stimulus, there is still a possibility that both processes drove the differential responding. The attentional disengagement process that directed attention away from the validly cued trials without a threat stimulus could drive attention bias. However, it is also possible that the attention engagement process drove attention bias, where the validly cued trial with a threat stimulus captured attention. Furthermore, even though participants were instructed that the cue predicted the location of the target most of the time, it is possible that participants did not shift their attention to the cue. Therefore, it cannot be assumed that initial fixation was achieved, thus, this task does not fully disentangle the attentional processes that underlie attention bias to threat.

Another example of an unsuccessful design that aimed to disentangle enhanced attentional engagement with, and difficulty disengagement from negative stimuli was attempted with the use of a single stimulus dot-probe task (Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Yiend & Mathews, 2001). In this version of the task, participants had to respond to probes that were presented either in the same (valid) or opposite (invalid) location of the previously presented schematic face. The schematic face contained either an angry, happy, neutral or scrambled expression and was presented for 500ms or 1000ms in the left or right position of the fixation cross. Typically, studies utilising this task show that anxious individuals have a slower response to probes that appear on the opposite location of the screen compared to the presented stimulus when that stimulus was negative rather than neutral (Fox et al., 2001). Furthermore, there was no differential responding to probes that were presented in the same location as the previously presented negative or neutral stimuli. This resulted in the conclusion that heightened anxiety vulnerability is characterised only by difficulty in disengaging attention from negative information (Fox et al., 2002; Yiend & Mathews, 2001), which is evidence for the *single biased attentional disengaging account*. However, the evidence of biased attentional disengagement could be misinterpreted as evidence of biased engagement. In other words, differential responding to a probe following negative stimulus vs neutral stimulus does not disentangle whether responses were slower due to an attention bias away from the validly cued trials with neutral valence rather than attentional capture towards the validly cued trials with negative valence. Furthermore, since this task only presents one stimulus at the time, it is unlikely that

is assessed attention bias. According to the attention bias theories described earlier, selective attention can only be biased if more than one stimulus is competing for attentional resources.

The methods described above are inadequate to disentangle attentional engagement with, and disengagement from negative, compared to neutral stimuli (Clarke, Macleod, & Guastella, 2013; Mogg, Holmes, Garner, & Bradley, 2008). According to Clarke et al. (2013), a task adequate in unravelling the two processes needs to adhere to three criteria. The first criterion states that such a task needs to control for systematic individual differences of general responding, for instance, the generally slower responding of anxious individuals in the presence of a threat (labeled "freezing"; Clarke et al., 2013; Mogg et al., 2008). The second criterion states that such a task should control for differences of initial focus on stimuli with different valence (Clarke et al., 2013). The third criterion states that such a task needs to include neutral baseline trials. These are needed to compare whether attention shifts slower or quicker to negative relative to neutral information.

A task proposed by both Rudaizky, Basanovic, and MacLeod (2014) as well as Grafton and MacLeod (2014) included these three criteria for disentangling the attention processes and further investigated whether the biased attentional engagement or disengagement accounts could be supported. Rudaizky et al. (2014) labelled the task *attentional engagement bias and disengagement bias assessment task* while Grafton and MacLeod (2014) labelled the task the *attentional response to distal vs proximal emotional information* (ARDPEI) task. To minimise confusion, this task will be labelled here as *attentional process assessment* (APA) task. The APA started each trial with two red frames, which were presented on the left and right side of the screen for 500ms. In one of the two frames, a little box was presented. The cue probe, which was either a horizontally or vertically presented line, would appear in that box after 250ms. Participants were instructed to attend to the box and remember the orientation of the cue probe. This ensured that the initial fixation of every participant in each trial was controlled for. Subsequently, two stimuli would appear for 250ms in the same location as the frames. These were either a negative or a neutral valence picture from the International Affective Picture System (IAPS) together with an abstract form of art. The neutral-abstract picture pair functioned as the baseline trial. Finally, the target probe (horizontally or vertically presented) appeared on either the left or right side of the screen and would stay on until a

response was made. Participants needed to match the orientation of the target probe to the cue probe as quickly as possible without making any mistakes.

The APA task allowed the calculation of two independent bias indices: one for the engagement bias and one for the disengagement bias. With this task, Rudaizky et al. (2014) demonstrated that elevated anxiety levels were independently associated with enhanced attentional engagement with, and impaired disengagement from negative relative to neutral stimuli. They concluded that both processes are unrelated to each other and that both independently underlie emotional vulnerability in anxiety. Similarly, Grafton and MacLeod (2014) found that individuals high in trait anxiety showed facilitated engagement with, and impaired disengagement from negative information compared to no attention bias in those with low trait anxiety. Both attentional bias types were found unrelated to each other. The finding that the attentional engagement bias was only found at a 500ms SOA, whereas the attentional disengagement bias was only found at a 100ms SOA, strengthened this. The conclusion that both attentional bias types were evident and independent patterns of attention bias related to anxiety is in contrast with both the *single biased attentional engagement account* (e.g., Mogg & Bradley, 1998) and the *single biased attentional disengagement account* (e.g., Fox et al., 2001). This improved methodology provided new evidence to support a *dual biased attentional process account*, wherein each bias type seems to be independently associated with heightened anxiety vulnerability.

Besides the single vs dual attention bias account debate, certain additional questions of interest in this research project have not yet gained much interest. Firstly, what process is (or which processes are) modified by a training procedure in the ABM paradigm? There are several possible outcomes. It is possible that the training procedure with the conventional dot-probe task only changes the attentional disengagement bias. For instance, it may be the case that the attention training, which repeatedly probes the neutral when competing with a negative stimulus, facilitates the attentional disengagement from negative stimuli. Furthermore, it is possible that the training only changes the attentional engagement bias, such that the training strengthens inhibition of the attentional engagement process with negative information. Lastly, it is possible that the dot-probe task trains both the inhibition of attention engagement and the facilitation of disengagement simultaneously, reducing both biases. The second question asks whether different training tasks have different effects on the change in attentional processes when ABM is employed. There is a

possibility that a training task, other than the dot-probe task, influences the attentional engagement and/or disengagement bias differently. This needs to be investigated as it is possible that different training approaches employ varying strategies that affect multitude of learning mechanisms and change different attentional processes. It is imperative to investigate these questions, as the answers may explain the variability of results in the ABM literature.

The second study, described in Chapter 4 of this thesis, addresses these two questions. The experiment was designed to gain an understanding of what process, or processes, are changed by the dot-probe task in an ABM procedure. The change of the two processes in the ABM paradigm was measured with the APA task (Grafton & MacLeod, 2014; Rudaizky et al., 2014) pre- and post-attention bias training. The dot-probe task was compared with another attention training task to investigate whether different training tasks change different attentional processes that underlie attention bias. In turn, this can provide important insights into whether the attentional engagement or disengagement processes are modified by a training procedure in the ABM paradigm and whether different training task have different effects on the change in attentional processes when ABM is employed. This knowledge will have sizable implications for the experimental and clinical fields, as it explains the mechanisms of change that underlie attention bias modification.

### **A Short Overview of the Thesis Outline**

The two studies outlined in this thesis will provide insights into the question how an attentional training procedure can successfully elicit a change in selective attention. The first study will investigate how the main learning mechanism of the dot-probe task influences selective attention when attention bias is modified in the ABM paradigm. This study will be divided into two chapters. Chapter 2 will discuss the three experiments that investigated the main learning mechanism with non-emotional stimuli. This chapter is written as a manuscript and is submitted to a journal where it is currently under review. Chapter 3 will discuss the two experiments that investigated the same learning mechanisms with emotional stimuli. The second study will be discussed in Chapter 4. This study investigated, in one experiment, how the attentional engagement and disengagement processes changed when different training procedures in the ABM paradigm were employed. The general discussion will discuss the findings of both studies in Chapter 5.

## Chapter 2

Attention Bias Modification with Non-Emotional Stimuli: Stimulus-Probe  
Associative Learning Mechanisms that Underlie Dot-Probe Task Assessment and  
Training of Selective Attention

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## Abstract

**Background and Objectives:** Attention bias has been associated with psychopathology and attention bias modification (ABM) training has shown promising results in changing attention bias and subsequently decreasing psychopathology. The dot-probe task is most commonly used to assess and change attention bias. This paper investigated the stimulus-probe associative learning mechanisms stipulated in the dot-probe task. **Methods:** Three experiments were conducted wherein the stimulus-probe associative learning was tested in a dot-probe task utilising two non-emotional images to eliminate elements of individual differences that come with emotional stimuli. In particular, the degree to which selective attention can be trained towards a non-emotional stimulus, the degree to which an acquired bias could be extinguished or reversed through exposure to a subsequently reversed training contingency, and the potential role of contingency awareness in attention bias acquisition were examined. **Results:** Evidence for attention bias training towards non-emotional stimuli emerged in the second contingency training, but not in the first training. Training effects were only evident on within-training assessment trials and did not transfer to post-training assessment trials suggesting that the contingencies used in the assessments seemed to influence selective attention. Furthermore, contingency awareness was associated with attention bias acquisition. **Limitations:** Awareness was measured at the end and not after every part of the experiment. Hence, it cannot be determined whether the lack of attention bias induction was due to the lack of contingency awareness. **Conclusions:** It was concluded that selective attention is very malleable and post-training assessments may not be optimal to assess attention bias change.

*Keywords:* Attention bias modification training (ABM), selective attention, dot-probe task, contingency awareness, contingency learning, stimulus-probe association

There is substantial evidence that attention bias for negative information is a reliable characteristic of emotional psychopathology (Aspen et al., 2013; Duque & Vázquez, 2015; Mark, Williams, Fraser, Watts, & Mathew, 1997; Schoth et al., 2012; Wabnitz et al., 2016). Given the proposed causal role of attention bias to negative information in the maintenance of emotional pathology, the dot-probe task has been developed to assess the presence of attention bias towards or away from threat in those high and low in emotional vulnerability (MacLeod et al., 1986). The dot-probe task assesses attention bias by presenting two stimuli in separate screen positions for a brief duration, one of them emotionally salient, the other one neutral. Subsequently, a probe appears in the location previously occupied by one of the two stimuli with a 50% congruency. Thus, both stimuli are followed by the probe equally often and have no predictive value. An attention bias towards emotion is evident when on average participants react quicker to probes presented in the location of an emotionally salient, compared to a neutral stimulus. Therefore, the dot-probe task can be used to assess whether the presence of attention bias is related to psychopathology, as predicted by attention and emotion theories (e.g., Buehlmann & Deco, 2008; Duncan, 2006; Williams et al., 1988).

Furthermore, the dot-probe task can also be used to train attention bias (MacLeod et al., 2002). In an attention bias training procedure, one stimulus type, which is either emotional or neutral in content, reliably predicts the location of the probe. For instance, after consistently presenting the probe in the neutral stimulus location it becomes advantageous to attend towards the neutral and away from the emotional stimuli. MacLeod et al. (2002) were the first to use the dot-probe task as a training tool. Participants were either trained to attend to neutral or negative stimuli and different attention bias patterns between participants were confirmed in a subsequent assessment. This attention training procedure has been labelled attention bias modification (ABM). Additionally, they found that compared to participants trained to attend to negative stimuli, those trained to attend to neutral stimuli were less emotionally vulnerable when completing a subsequent stress task. MacLeod et al. (2002) hereby established a causal link between changes in attention bias and changes in emotional vulnerability.

Many researchers have replicated the finding that successful bias change leads to changes in emotional vulnerability and highlighting its potential clinical utility in the treatment of emotional disorders (see for meta-analyses: Bar-Haim,

2010; Bar-Haim et al., 2007; Hakamata et al., 2010). However, many studies have also failed to observe emotional benefits following ABM (e.g., Cristea et al., 2015; Heeren et al., 2015; Mogoșe et al., 2014). Some suggest that ABM may not be as effective as initially thought, for instance, the meta-analysis conducted by Cristea et al. (2015) found significant medium effect sizes that, after the exclusion of outliers, and adjustment for publication bias, decreased, and often became non-significant. However, past studies did not always assess whether a change in attention bias had actually occurred during training. MacLeod and Clarke (2015) reviewed studies that did and did not report such a change and showed that those that did report a change also reported significant reductions of emotion vulnerability (with the exception of studies looking at spider fear). Though their conclusion was not statistically tested, more compelling support for the importance of a successful attention bias change in the ABM paradigm was provided by Grafton et al. (2017). They reanalysed the meta-analysis done by Cristea et al. (2015), controlled statistically for unsuccessful attention bias change, and found that ABM reliably impacted emotion vulnerability after successful bias change. However, a limitation of Grafton et al. (2017) is that they did not test the influence of a possible publication bias. Nevertheless, these results strongly imply that it is important to assess whether attention bias changed due to training in the ABM paradigm, before assessing its effect on emotion vulnerability (Clarke et al., 2014; MacLeod & Clarke, 2015).

Given that the clinical outcome appears to be dependent on the success of changing attention bias, it is important to understand the conditions most conducive to achieving such change. Over the course of the development of ABM research, the focus has changed quickly from investigating the causal relationship between selective attention and anxiety on a mechanistic level (MacLeod et al., 2002) to assessing the effectiveness of ABM as a clinical intervention for anxiety disorders (e.g., Cristea et al., 2015). However, the need to investigate the conditions under which paradigms, like the dot-probe task, produce the best training results remains imperative (Koster & Bernstein, 2015). The main mechanism that underlies selective attention training with the dot-probe task is the learning of stimulus-probe associations. These associations direct participants' selective attention to prefer the predictive stimulus, which is the stimulus that is consistently presented in the probe position. It is assumed that it becomes advantageous for the participants to attend towards the predictive stimulus as it increases the performance on the dot-probe

tasks. As a result, an attention bias is induced towards the stimulus that is consistently paired with the probe. In other words, participants learn that a certain stimulus predicts the location of the probe, and, therefore, learn to attend to this predictive stimulus.

It is important to determine the best conditions to establish the stimulus-probe association in the dot-probe task as this may enhance success in modifying attention bias. Therefore, the aim of this study is to establish a template wherein the dot-probe task was successful in establishing, changing, and assessing an attention bias towards stimuli by changing the stimulus-probe contingencies. To establish such a template, this study employed a dot-probe task utilising only non-emotional stimuli. Non-emotional stimuli were chosen because this avoided potential effects of individual differences resulting in higher homogeneity of the results. Emotional stimuli, like words or pictures can hold a variety of meanings. For instance, the word 'web' can be interpreted as 'world wide web' or as 'spider web'. Both interpretations can be perceived as neutral, positive or negative depending on personal likes, dislikes, and experiences. Since relatively faster RTs to probes after predictive stimuli compared to non-predictive stimuli represents learning of the stimulus-probe association, individual differences in stimulus interpretations are likely to confound the results. Therefore, non-emotional stimuli were used in the current study. These non-emotional stimuli consisted of black outlines of two shapes: a circle and a triangle.

Moreover, attention bias trainability assessed in previous studies solely relied on attention bias change measured from pre- to post-training assessments as most studies used a 100% contingency in the training phase. That is, the probe always followed one of the two stimuli. This set-up is unable to determine how attention bias transfers from assessment to training, and back to assessment within an ABM procedure. Furthermore, it may be problematic to assess trainability as a function of attention bias change measured from pre- to post-training assessments using the dot-probe task. Previous research has voiced concerns about the internal consistency of the dot-probe task (Chapman et al., 2017; Kappenman et al., 2014; Rodebaugh et al., 2016; Schmukle, 2005; Staugaard, 2009; Waechter et al., 2014), in particular the assumption that attention bias to threat is stable over time has been disputed (Rodebaugh et al., 2016; Zvielli et al., 2015). Therefore, the change from pre- to post-training can also contribute to the instability of attention bias. In the current study, the stimulus-probe contingency used in training was one of 95% congruency.

That is, the probe would replace one stimulus in 95% of the trials (labelled as *congruent trials*) and the other stimulus in 5% of the trials (labelled as *incongruent trials*). Thus, instead of relying on attention bias measured at pre- and post-training, training of selective attention would be indicated by quicker responding to probes on congruent relative to incongruent trials within the training phase.

The ABM paradigm used in the current study consisted of five phases, a baseline assessment, the first training (*training 1*), the first post-training assessment (*assessment 1*), the second (reversed contingency) training (*training 2*), and finally, a second post-training assessment (*assessment 2*). The baseline assessment tested the assumption that attention is not biased towards circles or triangles. Then, the two training phases tested the degree to which selective attention could be trained towards a non-emotional stimulus as well as the degree to which an acquired bias could be reversed through exposure to a reversed training contingency. The reversed training was added to the ABM paradigm to test whether an existing attention bias could be changed as tested in a conventional ABM. Firstly, this attention bias needed to be acquired in the first training as non-emotional stimuli, without any pre-existing bias were used. The two post-training assessment phases tested the degree to which an acquired attention bias was transferred from training to assessment. According to attentional theories of associative learning (Kruschke, 2003; Le Pelley, 2004; Mackintosh, 1975), it was expected that the change in selective attention created in training would be evident in post-training assessments. These theories predict that participants will react faster to probes, which follow stimuli that previously held predictive value.

In addition, participants' awareness of the stimulus-probe contingency may be imperative to learning the stimulus-probe association in the dot-probe task (Lovibond & Shanks, 2002). Previous research has provided mixed indications about the potential effect of stimulus-probe contingency awareness on the trainability of selective attention. Some argue that providing explicit instructions will generate potential resistance as well as conscious avoidance and, therefore, result in a less efficient training of attention bias (MacLeod, Mackintosh, & Vujic, 2009). Additionally, Koster et al. (2009) stated that selective attention training appears to "operate automatically, in the sense of proceeding swiftly without intention, and so is not readily amenable to volitional control" (p. 3). Despite these conventions, studies have shown that giving explicit instructions about the contingencies between the

stimuli and the probes led to stronger learning of selective attention in ABM (Grafton et al., 2014; Krebs et al., 2010; Lazarov et al., 2017). However, the explicit instructions resulted in a decreased subsequent effect of ABM on emotional vulnerability (Grafton et al., 2014). It may be that awareness of the stimulus-probe contingency in training needs to be acquired implicitly. Research into how many participants acquire awareness without explicit instructions and what the role of acquired contingency awareness is in the trainability of selective attention is currently lacking.

In summary, it was hypothesised that an attention bias towards one of two non-emotional stimuli could be generated within the initial training. Next, it was hypothesised that in the reversed contingency training, attention bias would be modified to the previously incongruent, now congruent stimulus. Furthermore, it was hypothesised that the attention bias produced in the training would be detectable in the post-training assessments. Finally, the current study also examined the association between contingency awareness and changes in patterns of selective attention to determine whether awareness of stimulus-probe association within training is associated with greater attention bias acquisition and change.

## **Experiment 1**

### **Methodology**

#### **Study Design**

The study design was a mixed factorial design, with one between-group and two within-group factors. The two within group factors were the order of contingency delivery (initial vs reversed), and the different assessments (within-training and post-training). The between-group factor was Group, where the experimental group was compared with a control group that received the same number of trials with a non-predictive contingency throughout. The baseline assessment was analysed separately to check the assumption that non-emotional stimuli do not compete for attention, and that, therefore, no attention bias was present at baseline.

#### **Participants**

One-hundred, and seventeen undergraduate students enrolled at Curtin University, Australia, volunteered to participate in exchange of course credit or \$15. Thirteen of the 60 participants in the experimental group were deleted from the data set as they made more than the pre-determined 20% errors ( $M_{PE} = 48$ ,  $SD = 25.5$ ,

range: 23.6 – 100). The remaining 47 participants averaged mistakes on 12% of the trials ( $SD = 3.57$ , range: 4.82 – 18.8). In the control group, 6 of the 57 participants made errors on more than 20% of trials ( $M_{PE} = 21.6$ ,  $SD = .973$ , range: 20.7 – 23.0). The other 51 averaged mistakes on 11% of trials ( $SD = 4.3$ , range: 3.39 – 20). The final sample consisted of 98 participants (72% female,  $M_{age} = 22.1$ ,  $SD = 5.11$ , age range: 18 – 45).

### **Procedure**

A maximum of four participants were tested at a time. On arrival, they were provided with an information sheet and completed a consent form. Participants rated all shapes before completing 10 practice and 560 dot-probe trials. For the experimental group, the dot-probe trials consisted of the baseline assessment, training 1, assessment 1, training 2, and assessment 2. The phases ran sequentially with a slight pause (+/- 100ms) during the loading of the next task component, which could potentially have alerted participants to a possible change in the task parameters. The control group completed 560 trials with 50% contingency. Subsequently, participants rated the shapes again, and completed the contingency awareness check. The total experiment took about twenty minutes. Finally, they were debriefed and thanked for their participation. The Human Research Ethics Committee at Curtin University approved this experimental procedure, and all other experiments reported in this chapter.

### **Materials**

#### **Stimulus Materials used in the Dot-Probe Task**

The dot-probe task was presented on a white background and the probes consisted of two black dots, either presented horizontally (‘..’) or vertically (‘:’). The size of the probes was 5mm in diameter (total stimulus size was 5x15mm). Pictures of a circle and a triangle were used as non-emotional stimuli. In the practice trials, pictures of a diamond and a square were used. The shapes were black outlines with white filling, presented on a white background and sized at 300x225 pixels.

#### **Dot-Probe Task**

The experiment was presented on a personal computer with a 19 inch monitor (screen resolution 1920x1080) controlled by DMDX (Forster & Forster, 2003) to ensure millisecond timing accuracy. Responses were collected on a QWERTY-keyboard with either the left and right shift key. The match between response key

and probe was counterbalanced across participants. Every trial started with a 500ms presentation of a fixation cross in the middle of the screen, followed by the two shapes presented next to each other for 500ms (960 pixels apart, measured from the centre of the stimuli). Then a probe was presented in the location of one of the two shapes, thus in the left or right location. Participants were instructed to respond as quickly as possible, without making mistakes, to the orientation of the probe. The probe would disappear after a response was made or after 1500ms. As described earlier, the experiment consisted of assessment and training phases. The assessment procedure consisted of 80 trials with a 50% stimulus-probe contingency, that is, the stimulus type did not predict the location of the probe. The training procedure consisted of 160 trials with a 95% stimulus-probe contingency, that is, on 95% of the trials, the probe followed the same stimulus ( $n_{\text{trials}} = 152$ ; *congruent trials*) and on 5% of the trials, the probe followed the other stimulus ( $n_{\text{trials}} = 8$ ; *incongruent trials*). The order in which the training contingencies were delivered was counterbalanced across participants such that half were first trained towards a circle and away from a triangle while the remainder were first trained towards a triangle and away from a circle.

The mean of 5000 random split-half reliabilities and the corrected Spearman-Brown reliabilities, in this as well as the following experiments, were assessed with the R package ‘splithalf’ version 0.3.1 according to Parsons (2018) and are shown in Table 4 of the Appendix at the end of this chapter.

### **Stimulus Ratings**

Participants rated all four shapes prior to, and post the dot-probe task, using a 15cm visual analogue scale (VAS) ranging from 0 “I do not like this shape at all” to 100 “I very much like this shape”. This was done to measure the explicit valence of the shapes. These rating can be found in the Table 3 of the Appendix at the end of this chapter.

### **Contingency Awareness Check**

Three questions were included at the end of the experiment to assess explicit awareness of any contingency: “Did you notice any regularities during the computer task?”. Answer options were yes or no, if answered yes, this was followed up with the open ended question: “What did you notice?”. Lastly, a multiple-choice question was asked: “Did the dots follow more after a certain shape?”, six contingency

options were given where participants could choose from: a) “No, the dots were presented equally often after both shapes”, b) “Yes, the dots came more often after the circle”, c) “Yes, the dots came more often after the triangle”, d) “This differed throughout the experiment, first more after the circle and then after the triangle”, e) “This differed throughout the experiment, first more after the triangle and then after the circle”, f) “I don’t know”, and g) “Other, namely...” (open response format). Participants in the experimental group were dichotomised into an aware or not aware category. Participants who selected any option indicating that there may have been a contingency involved were categorised as aware, even if they got it wrong, whereas the remainder were categorised as unaware. This liberal criterion was adopted because the contingency awareness check came at the end of the experiment, after multiple contingency changes. This was done to take into account that it was hard for participants to remember exactly what happened throughout the procedure.

### **Data Preparation**

Participants were excluded from the analyses if they made more than the pre-determined 20% of errors. Errors were defined as an incorrect button press, failure to respond within 1500ms, responses quicker than 100ms or an extreme score – values more than three standard deviations above or below each participant’s mean reaction time (RT) - and were entered as missing values. Analyses based on the proportion of errors were not significant, and are, therefore, not included in this paper.

Analyses were based on a bias index score. For all participants, the computation of this bias index score was based on the contingency in training 1. As such, the bias index score was calculated by subtracting mean RTs of congruent trials in training 1 from the mean RTs of incongruent trials in training 1. Hence, if selective attention was directed to the congruent stimulus in training 1, a significant positive bias index score would be expected, and if this effect was transferred to assessment 1, a positive bias index score would also be expected in assessment 1. If the training of selective attention in training 2 was successful in changing selective attention to the other stimulus, a significant negative bias index score would be expected in training 2. Similarly, a negative bias index score would be observed in assessment 2 if this change of selective attention was transferred to this final assessment.

For the control group, trials were labelled as congruent and incongruent to match the experimental group. That is, in the assessments, half of the participants were randomly allocated to an arbitrary condition wherein one stimulus was labelled

as congruent, and the other stimulus as incongruent. In the training, 5% of the trials that matched the serial position of incongruent trials in the experimental groups were randomly allocated to serve as incongruent trials (1 trial in a block of 20 trials). This way, the same number of trials were used in both groups to calculate an overall average of congruent ( $n_{\text{trials}} = 152$ ) and incongruent trials ( $n_{\text{trials}} = 8$ ). Table 2 in the Appendix at the end of this chapter shows the mean RTs for each trial type of experiments 1, 2 and 3.

### Statistical Analyses

Preliminary analyses showed that there was no evidence of order effects as to whether participants in the experimental group were first trained towards circles, and then triangles or vice versa. No significant differences were found between order conditions in a 5x2 (Phase [baseline vs training 1 vs assessment 1 vs training 2 vs assessment 2]) x (Stimulus order [circle-triangle vs triangle-circle]) ANOVA, all  $F < 2.29$ ,  $p > .075$ ,  $\eta^2 < .179$ . In the control group, there was no significant attentional preference for circles or triangles in all 5 phases: the difference scores between RTs of trials where the probe followed the circle or the triangle were not different from zero,  $t < 1.78$ ,  $p > .076$ .

The mean bias index score in baseline was compared between groups in a separate independent t-test. The mean bias index scores of the rest of the experiment were subjected to a 2 x 2 x 2 (Contingency [initial vs reversed] x (Assessment [within-training vs post-training]) x (Group [experimental vs control]) ANOVA. The effect of contingency awareness on training was not assessed for each experiment separately as only few participants became aware (see section Combined Analyses and the Role of Contingency Awareness). An alpha level of .05 was set for all statistically analyses.

## Results

### Baseline Patterns of Attention Bias

Figure 2 displays the bias index scores for the control and experimental group throughout the experiment. An independent t-test with equal variance not assumed between Groups confirmed that no difference in bias index scores at baseline was evident between the control and experimental group,  $t(86) = 1.05$ ,  $p = .298$ , 95%CI(-6.20, 6.49),  $d = 0.21$ .

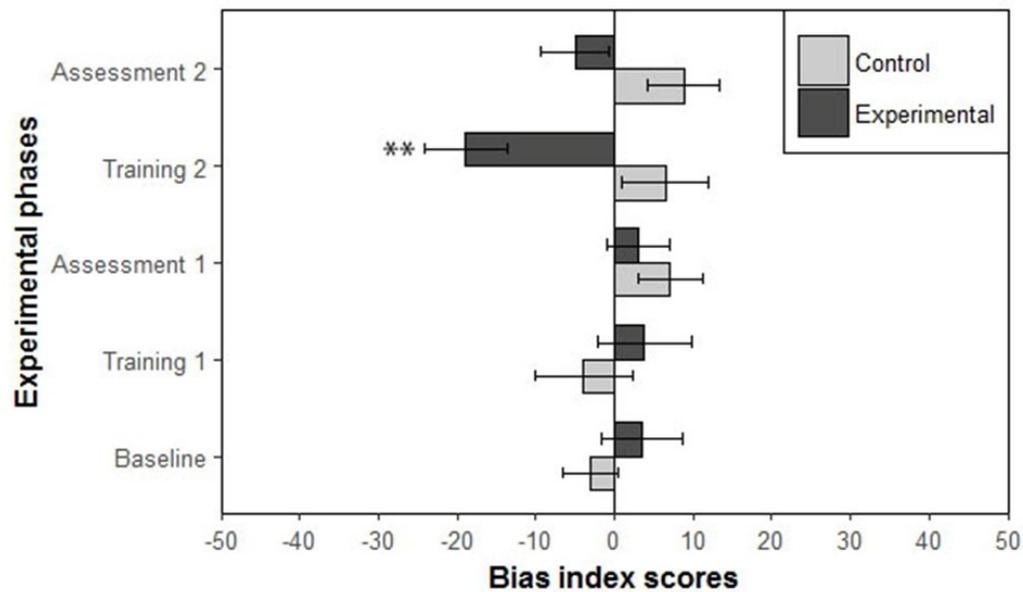


Figure 2. Mean Bias Index Scores in the Experimental and Control Groups of Experiment 1 as a Function of Phase. Error bars represent standard error of the mean.

\*\*  $p < .01$  (different from zero).

### Changes in Attention Bias in Response to Attention Bias Modification

As further illustrated in Figure 2, the ANOVA resulted in a significant main effect for Group,  $F(1,96) = 6.57, p = .012, \eta^2 = .064$ , a significant interaction between Contingency and Group,  $F(1,96) = 8.02, p = .006, \eta^2 = .077$ , and a marginal interaction between Contingency, Assessment, and Group,  $F(1,96) = 3.19, p = .077, \eta^2 = .032$ . Pair-wise comparisons indicated that the experimental group was not significantly different from the control group in training 1,  $F(1,96) = .801, p = .373, \eta^2 = .008$ , nor in assessment 1,  $F(1,96) = .517, p = .474, \eta^2 = .005$ . However, the experimental group was significantly different from the control group in training 2,  $F(1,96) = 10.9, p = .001, \eta^2 = .102$ , and in assessment 2,  $F(1,96) = 4.77, p = .031, \eta^2 = .047$ . Post-hoc one-sample t-tests split per group showed that the bias index score was significantly different from zero for the experimental group in training 2,  $t(46) = 3.35, p = .002, 95\%CI(7.53, 30.3)$ , however not in assessment 2,  $t(46) = 1.29, p = .204, 95\%CI(-2.82, 12.8)$ . It seems that attention bias towards the stimulus that predicted the probe was evident in training 2, but not maintained in the subsequent assessment task.

### Discussion

The first experiment was designed to test whether participants learned that a stimulus predicted the location of the probe, and, therefore, learned to attend to this predictive stimulus. Non-emotional stimuli (shapes) were used since these do not support a pre-existing attention bias. The findings confirmed this assumption: there

was no attention bias evident in the baseline assessment, participants reacted similarly to probes presented in the location of both non-emotional stimuli. Furthermore, the results showed that there was no acquisition of attention bias in response to the first training. However, an attention bias was evident in the second training: participants responded quicker to the probes in congruent trials, compared to probes in incongruent trials. There was no evidence that the attention bias induced in the training transferred to the post-training assessment. Given that no attention bias was acquired in training 1, transfer to assessment 1 was not expected. However, the attention bias acquired in training 2 did not transfer to assessment 2.

It seems surprising that the dot-probe task was unsuccessful in training an attention bias in the first training, while it was successful in the second training. This may be an effect of the initial baseline assessment which pre-exposed participants to 80 non-predictive trials. Thus, participants were potentially less sensitive to the subsequent introduction of the stimulus-probe contingency in training 1. Such pre-exposure effects have been shown to slow down learning (Baker & Mackintosh, 1979; Lubow & Moore, 1959; Mackintosh, 1975). A second question to consider is why the stimulus-probe association learned in training 2 does not carry-over to the assessment post-training as predicted by attentional theories of associative learning (Kruschke, 2003; Le Pelley, 2004; Mackintosh, 1975). These theories predict that participants will react faster to probes that followed stimuli, which previously held predictive value. However, it seems that participants learn to attend to a certain stimulus during the training phase because it predicts the probe. During assessment, participants may learn that this predictive relationship no longer exists, which results in a reduction of attention bias.

Nevertheless, it is problematic that the assessment post-training does not capture the attention bias induced in the training. Most studies that measured successful modification of attention bias in an ABM paradigm relied on a bias change score calculated from bias scores measured in assessments pre- to post-training (e.g., Hallion & Ruscio, 2011). Previous studies that found non-significant bias change from pre- to post-training assessments in ABM may have successfully changed the attention bias in training, however, this change may not have been detected in the post-training assessment. These results suggest that the assessment may function as a re-training of selective attention to attend to both stimuli equally,

instead of assessing attention bias. However, such a finding requires replication before any more concrete conclusions can be drawn.

## Experiment 2

The main aim of the second experiment was to test the pre-exposure hypothesis. If it is the case that pre-exposure interferes with bias acquisition in training 1, then the removal of the baseline assessment should result in an attention bias as a result of this first training. The additional aim of the second experiment was to replicate the absence of transfer of an acquired bias from training to assessment observed in experiment 1. In summary, this second experiment used the same procedure as the experimental group of Experiment 1 with the omission of the baseline assessment. The data of this new group were then compared to the first 480 trials of the control group of Experiment 1.

## Methodology

### Participants

Forty-six undergraduate students, enrolled at Curtin University, Australia, volunteered to participate in exchange of course credit or \$15. Six of the participants were deleted from the data set as they made more than the pre-determined 20% errors ( $M_{PE} = 26$ ,  $SD = 2.95$ , age range: 22.7 – 30.8). The final sample consisted of 40 participants who made on average 10% errors ( $SD = 3.74$ , range: 2.92 - 17.9), 30 participants were female ( $M_{age} = 21.0$ ,  $SD = 2.56$ , age range: 18 – 29).

### Procedure

The same procedure was followed as described in Experiment 1, the only differences being that participants did not complete a baseline assessment, and that all participants were in the experimental condition. It took participants approximately 15 minutes to complete the experiment.

### Materials

The same materials were used as described in Experiment 1.

### Data Preparation and Statistical Analyses

Analyses, statistical outcomes, and thresholds were based on the same criteria as described in the methodology of Experiment 1. Preliminary analyses showed that there was no evidence of order effects as to whether participants were first trained towards circles, and then triangles or vice versa. The analysis revealed a main effect for Phase,  $F(3,36) = 7.57$ ,  $p = .001$ ,  $\eta^2 = .354$ , which did not interact with stimulus-order, all  $F < .611$ ,  $p > .439$ ,  $\eta^2 < .016$ . Hence, the mean bias index scores of each

block were subjected to a 2 x 2 x 2 (Contingency [initial vs reversed]) x (Assessment [within-training vs post-training]) x (Group [experimental vs control]) mixed-design ANOVA.

## Results

### Changes in Selective Attention in Response to Attention Bias Modification

Figure 3 shows the mean bias index scores for each group at each assessment point.

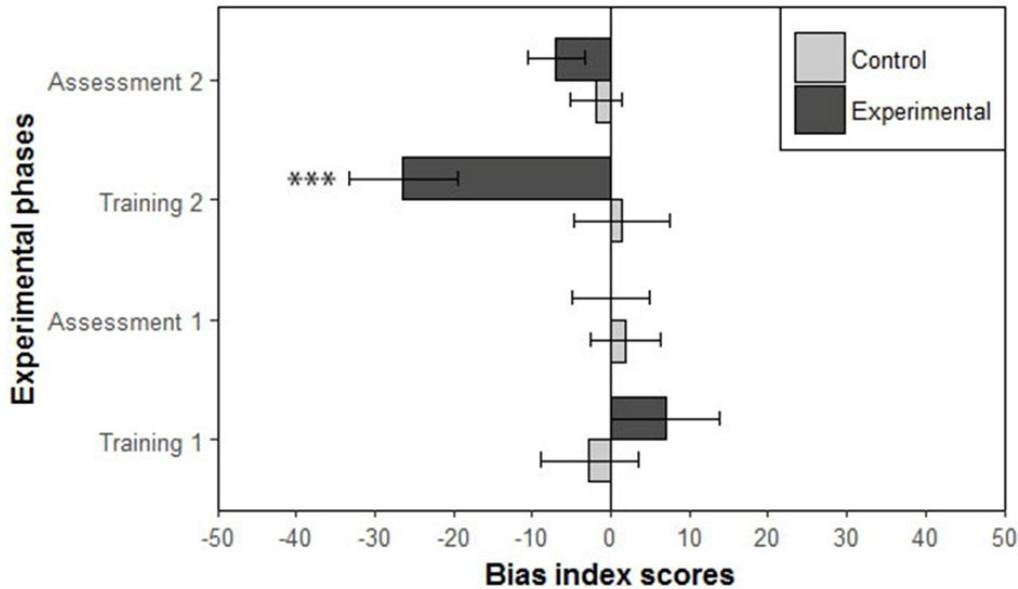


Figure 3. Mean Bias Index Scores in the Experimental and Control Groups of Experiment 2 as a Function of Phase. Error bars represent standard error of the mean.

\*\*\*  $p < .001$  (different from zero).

The ANOVA showed a main effect of Contingency,  $F(1,89) = 7.01, p = .010, \eta^2 = .073$ . The Contingency by Group interaction,  $F(1,89) = 7.25, p = .008, \eta^2 = .075$ , and the Contingency by Assessment by Group interaction were significant,  $F(1,89) = 5.97, p = .017, \eta^2 = .063$ . Similar to the previous experiment, pair-wise comparisons between Groups indicated that the experimental group differed from the control group in training 2,  $F(1,89) = 9.18, p = .003, \eta^2 = .093$ , but not in training 1,  $F(1,89) = 1.08, p = .302, \eta^2 = .012$ , or in either assessment post-training,  $F < 1.05, p > .309, \eta^2 < .012$ . Omitting the baseline assessment seems not to facilitate training of selective attention in training 1, which is inconsistent with the pre-exposure hypothesis.

## Discussion

The second experiment was designed to further investigate stimulus-probe associative learning in the dot-probe task. It was tested whether by omitting the baseline assessment participants would learn that a certain stimulus predicted the

location of the probe, and, therefore, attend to this predictive stimulus. Consistent with the results of Experiment 1, an attention bias was acquired in the second training and not in the first, and there was no transfer from the training to the post-training assessment. Additionally, eliminating the baseline assessment did not facilitate the acquisition of an attention bias towards the congruent stimulus in training 1. These findings are inconsistent with the pre-exposure hypothesis and the opposite of what was expected based on the pre-exposure literature (Baker & Mackintosh, 1979; Lubow & Moore, 1959; Mackintosh, 1975).

The failure to see an attentional bias in training 1 may be caused by the simplicity of the task which meant that participants did not use the stimuli to facilitate the identification of the probe location. While training of spatial selective attention was the goal of the current experiments, the participants' task was to differentiate between two probes, a task that can be performed without attending to the preceding stimuli. Given that the probes were relatively large and on the screen for a relative long time, they were potentially easy to detect without requiring the use of the stimuli to predict their location. If this were true, increasing the difficulty to detect the probes could potentially motivate participants to use the stimuli to facilitate probe detection and so contribute to greater changes in selective attention in line with the contingency. As such, the purpose of Experiment 3 was to examine the hypothesis that a more difficult dot-probe task would facilitate the acquisition and change of attention bias in training 1 and 2. Furthermore, would Experiment 3 replicate the absence of transfer of acquired bias from training to post-training assessment, then there would be strong evidence to suggest that an assessment post-training may underestimate the attention bias acquired during training.

### **Experiment 3**

Based on the results of the previous two experiments, Experiment 3 was designed to test the hypothesis that increasing the difficulty of probe identification would increase the reliance on the preceding stimuli, and so enhance the effects of training on selective attention. To increase the likelihood that the shapes would be processed as a predictor of the probe, the dot-probe task was modified. Specifically, the detection of the probe was made more difficult by changing probe size and exposure duration from 15mm and 1500ms to 4 mm and 250ms, respectively.

## Methodology

### Participants

Sixty-eight Mechanical Turk workers volunteered to participate in exchange of \$5 USD. Because the task was harder to perform, more errors were anticipated, and therefore, the pre-determined exclusion criterion was changed from 20% to 30%. Of the 68 participants in the study, 22 were deleted from the data set as they made more than 30% of errors ( $M_{PE} = 70.9$ ,  $SD = 23.7$ , range: 33.3 – 99.8). The final sample consisted of 46 participants (33% female,  $M_{age} = 33.6$ ,  $SD = 6.92$ , age range: 20 – 48) who made 12% errors on average ( $SD = 6.13$ , range: 1.6 – 26.6).

### Procedure

The same procedure was followed as described in Experiment 2, the only differences was that the whole procedure was hosted online via Turk prime (Litman, Robinson, & Abberbock, 2017), and the pre-and post-ratings of the shapes were omitted. Instead, strategy to perform the dot-probe task was assessed at the end of the experiment. Similarly, no control group was tested. It took participants approximately 20 minutes to complete the experiment.

### Materials

The same materials were used as described in Experiment 1, unless otherwise specified.

### Strategy

One open-ended question (“Did you use a certain strategy?”) was included to assess the strategy used by the participant to perform the dot-probe task.

### Dot-Probe task

The same dot-probe task was used as in the previous experiments; the only difference was that the probe was decreased in size from 15mm to 4mm, and the exposure duration of the probe from 1500ms to 500ms.

### Data Preparation and Statistical Analyses

Analyses, statistical outcomes and errors were based on the same criteria as described in the methodology of Experiment 1. Preliminary analyses showed no effect of stimulus order in training, all  $F < 1.33$ ,  $p > .279$ ,  $\eta^2 < .088$ . The mean bias index scores of each block were subjected to a 2 x 2 (Contingency [initial vs reversed] x (Assessment [within-training vs post-training])) repeated measures factorial ANOVA.

## Results

### Changes in Selective Attention in Response to Attention Bias Modification

Illustrated in Figure 4, the ANOVA did not result in any significant effects, all  $F < 1.36$ ,  $p < .250$ ,  $\eta^2 < .030$ . Increasing the difficulty level of the task seemed to impede the acquisition of attention bias, even in training 2.

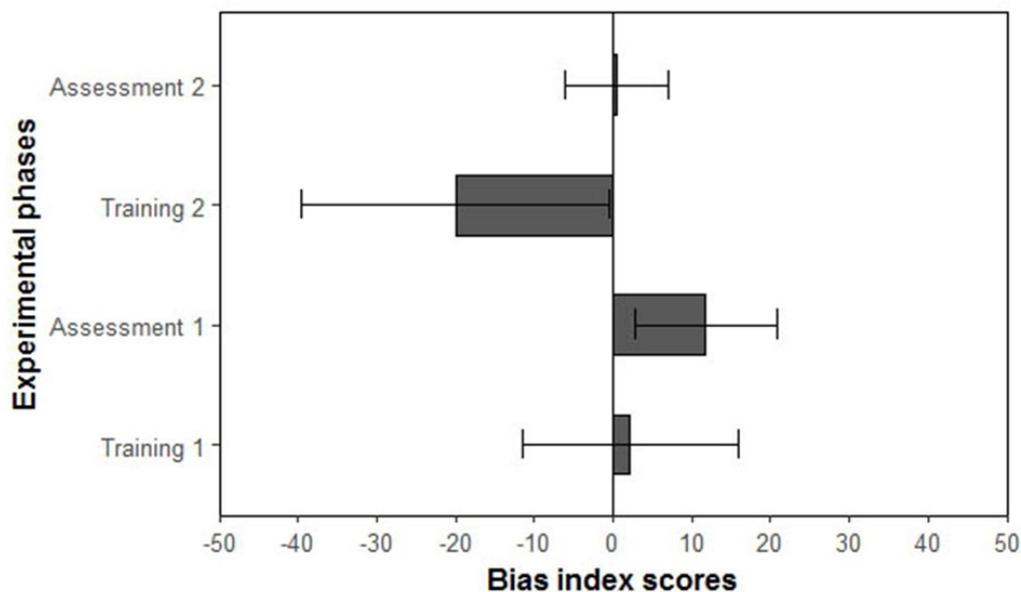


Figure 4. Mean Bias Index Scores in the Experimental Group of Experiment 3 as a Function of Phase. Error bars represent standard error of the mean.

### Strategies Used to Perform the Dot-Probe Task

Qualitative responses were categorised into four themes and are reported in Table 1, these were: (1) No strategy used (“No”); (2) Focused on the probes (“No I just reacted to dots as they came”); (3) Focused on certain location of the screen (“I tried to focus on one side and then look at the other if the dots weren't on the first side”); (4) Shape predicted the probe (“Yes, trying to figure out which shape they came after most of the time”).

Table 1.

### Strategies Used to Perform the Dot-Probe Task in Those Aware and Not Aware of the Stimulus-Probe Contingency

Themes	Aware of Contingency	Not Aware of Contingency
No strategy used	$n = 5$ (36%)	$n = 21$ (68%)
Focused on the probes	$n = 5$ (36%)	$n = 7$ (22%)
Focused on certain location of the screen	$n = 1$ (7%)	$n = 3$ (10%)
Shape predicted the probe	$n = 3$ (21%)	$n = 0$ (0%)

The kind of strategy used differed for those categorised as aware and not aware of the contingency,  $X^2(3) = 9.05$ ,  $p = .029$ ,  $\phi = .448$ . However, since the number of participants in each theme is very low, no inferences are made on this data.

### **Discussion**

Contrary to what was hypothesised, the more difficult dot-probe task did not support training of an attention bias in training 1 or training 2. The results suggest that participants do not alter their pattern of attention selectivity in response to the training or assessment phases of the more difficult version of the dot-probe task. Increasing the difficulty to detect the probes did not motivate participants to use the stimuli to facilitate probe detection and so, did not contribute to greater changes in selective attention in line with the contingency in training 1 or 2. As such, the hypothesis that a more difficult dot-probe task would facilitate the acquisition and change of attention bias in training 1 and 2 was rejected.

A limitation of this experiment was that compared to the previous two experiments the variability of the bias scores was slightly larger and more people needed to be excluded based on poor accuracy (Exp. 1: 22% and Exp. 2: 15% with a 20% error cut-off point; Exp. 3: 32% with a 30% error cut-off point). This resulted in lower power of the design. The difference in variability may be due to the different sample used (undergraduate Australian students vs American M-Turk workers) as well as a different delivery of the dot-probe task (controlled laboratory vs uncontrolled home environment). However, the data obtained in the lab were not all that less noisy, it seems that noisy data is a general issue when using the dot-probe task. Sample sizes need to be increased, especially as it is essential to look at verbalisers only (i.e., those who report to be aware of the contingency). To address the sample size issue, the data of the three experiments were combined into one analysis. This could potentially illuminate the effects by increasing the power of the design.

### **Combined Analyses and the Role of Contingency Awareness**

The three experiments described above resulted in somewhat inconsistent findings. The general pattern found was that training effects were only registered on the within-training assessment trials of training 2, not training 1, and that this effect did not transfer to post-training assessment trials. However, these effects were not replicated in the last experiment where a more difficult dot-probe task was used.

## AN INVESTIGATION INTO ATTENTION BIAS MODIFICATION

However, the variability in the last experiment was larger compared to the previous two experiments and it may have lacked the power to replicate the findings. Since the three experiments trained the same stimulus-probe associations, the data of the three experiments were combined to increase the power of the design.

To explore whether contingency awareness is associated with the acquisition and change of attention bias, participants of all experimental groups were dichotomised into aware and not aware of a stimulus probe category and the data of training 1 and 2 were analysed. It was hypothesised that those who reported some level of awareness of a stimulus-probe contingency would show greater bias of selective attention to the congruent probe within the training assessments compared to those who reported no awareness at all of the stimulus-probe associations.

### Results

#### Changes in Selective Attention in Response to Attention Bias Modification

Figure 5 displays the attention bias index scores for the two within-training and post-training assessment phases collapsed across experiments.

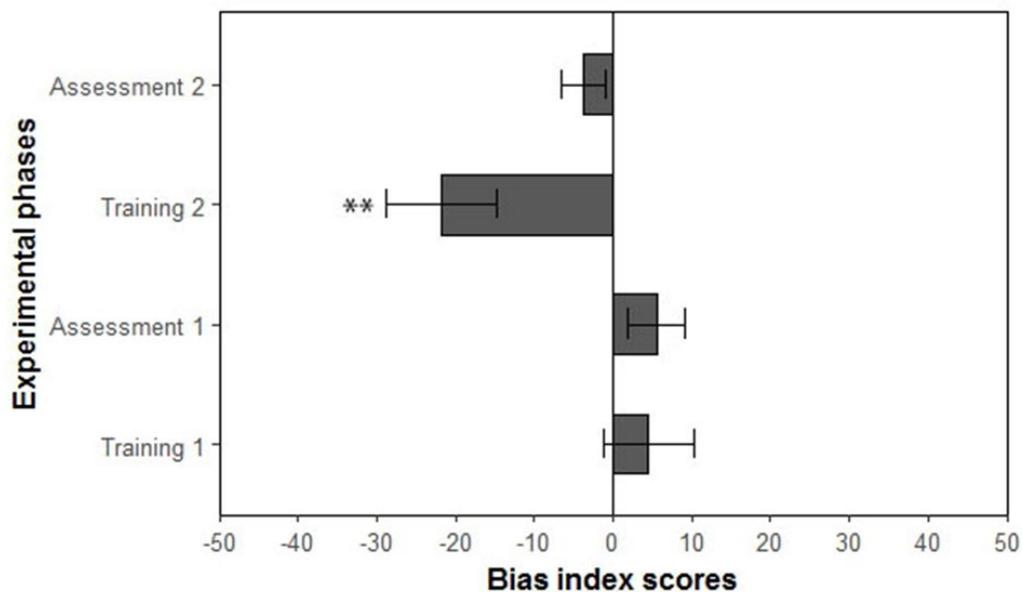


Figure 5. The Attention Bias Index Scores for the Two Within-Training and Post-Training Assessment Phases Collapsed Across Experiments 1, 2 and 3. Error bars represent standard error of the mean.

\*\*  $p < .01$  (different from zero).

The one-sample t-tests showed that the attention bias was successfully induced in training 2,  $t(132) = 3.07$ ,  $p = .003$  two-tailed, 95%CI(-35.9, -7.74), but not in the other phases, all  $t < 1.31$ ,  $p > .134$ . Paired samples t-test between the bias assessed in training 2 and assessment 2 showed that there was a significant difference between the two phases,  $t(131) = -2.30$ ,  $p = .023$  two-tailed, 95%CI(-33.1, -2.50),  $d =$

0.28. These results imply that across the three experiments an attention bias was not trained in training 1, but only in training 2, and that the bias did not transfer to the subsequent assessment.

### Awareness of Stimulus-Probe Contingency and its Influence on Attention Bias Modification

Figure 6 displays the attention bias index scores for each experiment across the two training phases for those categorised as aware or not aware of the stimulus-probe contingency.

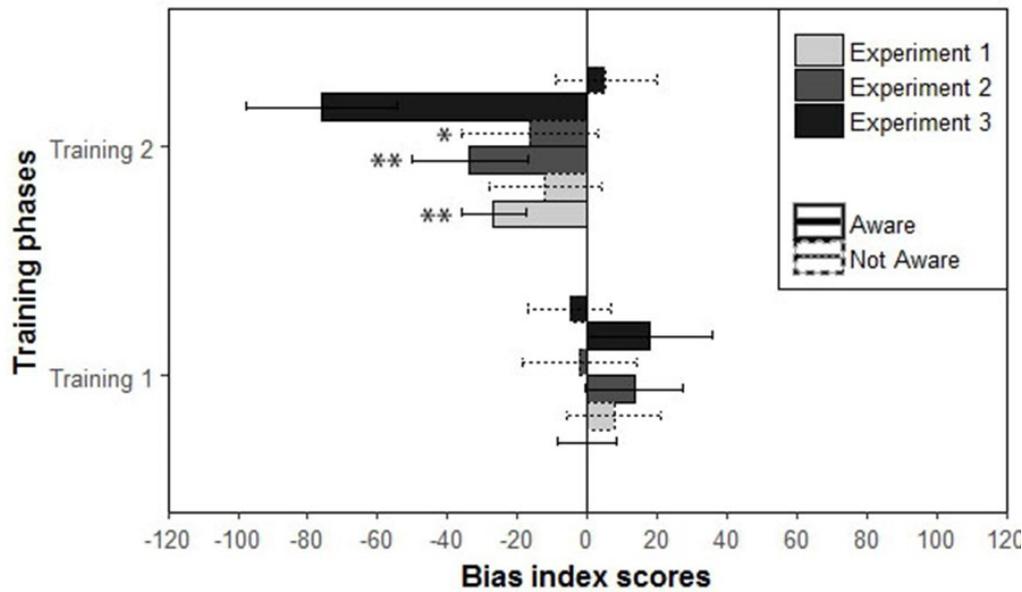


Figure 6. The Attention Bias Index Scores for Experiment 1, 2 and 3 across the Two Within-Training Phases for Those Categorised as Aware or Not Aware of the Stimulus-Probe Contingency. Error bars represent standard error of the mean.

\*\*  $p < .01$ ; \*  $p < .05$  (different from zero).

In Experiment 1, 47% were categorised as aware ( $n = 22$ ), in Experiment 2, 56% ( $n = 23$ ), and in Experiment 3, 31% ( $n = 14$ ). The 2 (Training [training 1 vs training 2]) x 2 (Awareness [aware vs not aware]) x 3 (Experiment [exp.1 vs exp.2 vs exp.3]) repeated measures ANOVA resulted in a main effect of Training,  $F(1,126) = 11.1, p = .001, \eta^2 = .081$ , and a significant interaction between Training and Awareness,  $F(1,126) = 6.28, p = .013, \eta^2 = .047$ . Pair-wise comparisons indicated that there was a significant difference between those categorised as aware or not aware in training 2,  $F(1,126) = 6.81, p = .010, \eta^2 = .051$ , but not in training 1,  $F(1,126) = .709, p = .401, \eta^2 = .006$ . This effect did not interact with Experiment,  $F(2,126) = 2.35, p = .100, \eta^2 = .036$ . All other effects were not significant,  $F < 2.23, p > .138, \eta^2 < .017$ . These results indicate that across the three experiments, the bias index scores measured in the second training interacted with contingency awareness.

Those aware of a stimulus-probe association showed faster responding to the probe that followed the predictive stimulus, indicating greater training of selective attention.

### **Discussion**

The final combined analysis supported the general observation that across studies attention bias training to non-emotional stimuli was only evident in the second training, not in the first training. This suggests that the null findings of training 1 did not occur due to the baseline assessment (Experiment 1 vs Experiment 2 and 3), or the difficulty level of the dot-probe task employed (Experiment 1 and 2 vs Experiment 3). Additionally, the results showed that the training effect in the second training was observed only in the within-training assessment and not in the post-training assessment. This implies that the attention bias induced within-training does not transfer to the assessment post-training, suggesting that the expression of selective attention is highly sensitive to changes in contingency, and may not persevere once a training contingency is entirely removed.

Secondly, the hypothesis that contingency awareness may be associated with the acquisition and change of attention bias in training was explored. Firstly, it was found that between 30 to 50% of the participants reported some awareness of a stimulus-probe contingency across studies. Secondly, analyses indicated that there was a significant difference in changes in selective attention between those categorised as aware versus those categorised as not aware of the stimulus probe contingency. Participants who reported awareness of a stimulus-probe contingency showed a significant attention bias in training 2, whereas the attention bias was not significantly different from zero in those who reported no awareness of any contingency. Importantly, this result did not interact with Experiment. These findings imply that awareness of the stimulus-probe contingency is associated with attention bias acquisition.

### **General Discussion Experiments 1, 2 and 3**

Three experiments were conducted to investigate attentional responses to stimulus-probe associations in the dot-probe task, with the over-arching aim of establishing a template to investigate the initial acquisition, retraining, and assessment of selective attention. In doing so, these studies also examined how attention bias assessed during blocks of training trials transferred to discrete assessment blocks. It was hypothesised that an attention bias towards a non-

emotional stimulus can be trained by placing the probe 95% of the time in the same location of one of two visually distinct stimuli (circle or triangle). Furthermore, it was hypothesised that by reversing the stimulus-probe contingency, an attention bias can be retrained to the opposite stimulus in a second training. Next, it was hypothesised that the post-training assessment would capture the attention bias created in the previous training. Moreover, this study explored the association between contingency awareness assessed at the end of the experiment and selective attention manipulated in the training phases.

Across experiments, evidence for an acquired bias in selective attention was found only in the second, and not in the first training. These results provided partial support for the first hypothesis, the dot-probe task was able to train attention bias to a non-emotional congruent stimulus, however not in both training phases. The possibility that pre-exposure to 80 non-predictive baseline assessment trials impeded learning of an attention bias in training 1 due to the learned irrelevance of the stimulus-probe contingency was tested in Experiment 2, however, the results did not favour this hypothesis. Overall, with or without a baseline assessment procedure, participants did not show evidence of an attentional preference for the congruent relative to the incongruent stimuli in training 1. The third experiment examined whether a more difficult version of the dot-probe task than used in the first two experiments would encourage participants to use the stimuli as predictors of the probes. This may in turn aid learning of the stimulus-probe contingency in training 1. However, no evidence of an acquired attention bias towards the congruent stimuli in any experimental phase was observed in Experiment 3. Therefore, Experiment 3 provided no evidence that increasing the difficulty of the task to make probes harder to distinguish, would facilitate learning of a stimulus-probe contingency.

However, we did find evidence that awareness of the stimulus-probe contingency accompanied acquisition of an attention bias. It was found that participants, who reported at the end of the experiment that they were aware of a stimulus-probe contingency, showed evidence of bias change in the direction consistent with training, however, only in training 2, and again, not in training 1. Participants unaware of the predictive function of the stimuli did not acquire an attention bias. It is possible that over time, participants became more aware of the stimulus-probe contingency as the experiment progressed, and after they experienced a shift in contingency, which can explain the null findings in training 1. Nevertheless,

an important limitation was that awareness was measured only at the end and not after every part of the experiment. This approach cannot determine whether the lack of attention bias induction in training 1 was due to the lack of contingency awareness in that phase. Therefore, future studies could usefully seek to measure contingency awareness in every phase, preferably without influencing participants' further stimulus-probe learning. This may be done by measuring visual mismatch negativity using an EEG, an event-related potential (ERP) sensitive to violations of learned statistical contingencies (Arad, Abend, Pine, & Bar-Haim, 2018). Arad et al. (2018) found that mismatch negativity clearly indicated contingency awareness during ABM. Another means of assessing contingency awareness may be to use online expectancy rating trials, wherein participants are asked to predict the location in which the next probe will appear. These could be implemented by presenting intermittent test trials where two question marks will appear instead of a probe requiring participants to indicate the probable location of the probe. Such an approach could in principle determine whether contingency awareness precedes training of attention bias.

Across experiments it was also found that at least half of the participants in the experimental groups did not become aware of the contingency. Given that individual differences in acquiring awareness of the contingency may play a role in the malleability of selective attention, further research is needed to determine what underpins individual differences in the probability that they will become aware of the contingency. Or more specifically, why some people fail to become aware. This in turn can provide helpful insights in the efficacy of attention bias training. Further research into individual differences of acquiring contingency awareness in ABM is particularly important since previous research has given mixed indications about the influence of awareness of the stimulus-probe contingency on the trainability of selective attention in ABM. Some studies showed that the contingency awareness needs to be acquired implicitly to reliably modify selective attention in training (Bar-Haim, 2010; Hertel & Mathews, 2011). Others showed that giving explicit instructions led to stronger changes in selective attention in ABM, though, these instructions also reduced the effects of ABM on subsequent emotion reactivity (Grafton et al., 2014; Lazarov et al., 2017). This study adds to these findings by showing that no consistent changes in attention in line with the contingency were found among those who did not indicate awareness of a stimulus-probe association,

while such changes were evident in those who reported awareness. This indicates that an awareness of the possible presence of a stimulus-probe contingency was associated with change in selective attention in line with the training contingency.

Besides, in accordance with the attentional theories of associative learning (Kruschke, 2003; Le Pelley, 2004; Mackintosh, 1975) it was hypothesised that any pattern of selective attention evident within training would be maintained and observed during the subsequent post-training assessment phase where participants would react faster to probes after stimuli that previously held predictive value. However, no support was found for this hypothesis across the three experiments where the stimulus-probe contingency changed from a predictive contingency in training to a non-predictive contingency in assessment. The bias index scores were not significantly different from zero in the assessment following the successful training. Our results were in line with those of Le Pelley, Vadillo, and Luque (2013), who found that the predictiveness of a stimulus generated in a previous task was quickly extinguished, and did not yield significant differences in a subsequent dot-probe task. As such, the current results clearly suggest that the post-training assessment of attention bias is unlikely to represent the pattern of bias acquired during training, because the pattern of bias is reactive to the assessment.

It may be of interest to develop different post-assessment procedures where, for instance, subtle changes to the contingencies are introduced, rather than an abrupt change. According to the exploration-exploitation decision making hypothesis (Daw, O'Doherty, Dayan, Seymour, & Dolan, 2006; Laureiro-Martínez, Brusoni, Canessa, & Zollo, 2015), when the contingency radically changes, the context will also change radically from training to assessment, and participants aware of the contingency will explore other strategies to maximise task performance. Instead, if the context gradually changes by incrementally altering the contingency, participants may be less likely to alter the strategy used in training. Consequently, the bias acquired in training may be more likely to be evident in post-training assessment. Future research should investigate how attention bias change can be assessed without the assessment influencing the attention bias patterns acquired during training. Besides changing the contingency more subtly, attention bias can possibly be measured in a more direct way, overcoming the need for any change in contingencies, for instance, by employing a free viewing task measuring eye-gaze as suggested by Armstrong and Olatunji (2012).

### **Conclusion**

Across three experiments evidence was found for attention bias training towards non-emotional stimuli in a second, reversed contingency training, but not in the initial training. Training effects were only registered on within-training assessment trials and did not transfer to post-training assessment trials. This suggests that the non-predictive contingency during assessments seemed to extinguish patterns of selective attention acquired during training. Therefore, it was proposed that selective attention is very malleable and dependent on the stimulus-probe contingency used in the ABM procedure. It was suggested that future research should use other methods to assess attention bias change after training. Furthermore, at least 50% of participants did not acquire awareness and attention bias was not induced in those who did not report contingency awareness. It would be beneficial for future research to investigate individual differences in acquiring contingency awareness, as well as how contingency awareness is associated with attention bias acquisition.

The series of experiments reported here investigated stimulus-probe associative learning mechanisms that underlie ABM training as well as assessment and can inform ABM efficacy. However, it is suggested that these results are replicated with the use of emotional stimuli, controlling for individual differences, before applying these findings in a clinical context.

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## Appendix Chapter 2

Table 2

*Mean Reaction Time Scores of Congruent and Incongruent Trials in all Experiments and Groups of Chapter 1*

Group	Aware	Block	Trial	<i>M</i> ( <i>SD</i> )	<i>S</i> , <i>K</i>
Experiment 1 ( <i>n</i> = 47)	Yes ( <i>n</i> = 22)	Baseline	Congruent	523(56.7)	-.215, -.604
			Incongruent	524(52.7)	-.576, -.090
		Training 1	Congruent	520(54.2)	-.266, -.787
			Incongruent	519(69.5)	.456, -.421
		Assessment 1	Congruent	526(64.3)	.720, -.173
			Incongruent	530(63.0)	.603, -.827
		Training 2	Congruent	513(57.2)	.168, -.678
			Incongruent	540(71.2)	-.717, .721
	Assessment 2	Congruent	502(50.9)	.379, .115	
		Incongruent	511(59.8)	.508, .425	
	No ( <i>n</i> = 25)	Baseline	Congruent	553(65.5)	.039, -.970
			Incongruent	558(67.7)	.028, -1.28
		Training 1	Congruent	531(49.4)	.585, -.526
			Incongruent	538(66.6)	.695, -.372
		Assessment 1	Congruent	547(62.7)	.802, .281
			Incongruent	550(64.4)	.621, .240
Training 2		Congruent	522(48.5)	.555, -.841	
		Incongruent	534(67.8)	.758, -.154	
Assessment 2	Congruent	520(57.4)	-.115, -1.05		
	Incongruent	521(54.8)	.175, -.319		
Experiment 2 ( <i>n</i> = 50 )	Yes ( <i>n</i> = 23)	Training 1	Congruent	521(62.3)	.187, -.848
			Incongruent	534(69.3)	.217, -1.32
		Assessment 1	Congruent	509(55.9)	.439, -.991
			Incongruent	511(60.1)	1.02, .481
		Training 2	Congruent	498(57.7)	.140, -1.09
			Incongruent	531(69.5)	.436, .008
	Assessment 2	Congruent	492(49.4)	.469, .406	
		Incongruent	498(52.1)	.564, 1.09	
	No ( <i>n</i> = 17)	Training 1	Congruent	522(56.8)	.284, -.570
			Incongruent	520(68.1)	1.55, 2.34
		Assessment 1	Congruent	514(57.7)	.550, -1.10
			Incongruent	511(61.7)	-.117, -1.45
Training 2		Congruent	497(57.4)	.171, -1.44	
		Incongruent	514(59.3)	.433, -.320	
Assessment 2	Congruent	496(62.9)	-.008, -1.41		
	Incongruent	504(65.2)	-.187, -.403		
Experiment 3 ( <i>n</i> = 45)	Yes ( <i>n</i> = 14)	Training 1	Congruent	659(175)	.866, .187
			Incongruent	677(170)	.248, -1.28
		Assessment 1	Congruent	619(135)	.495, -.817
			Incongruent	659(145)	-.158, -1.28
		Training 2	Congruent	597(151)	.000, -1.28
			Incongruent	673(178)	.850, .128

Group	Aware	Block	Trial	<i>M(SD)</i>	<i>S, K</i>		
	No ( <i>n</i> = 31)	Assessment 2	Congruent	607(113)	.160, -.587		
			Incongruent	605(115)	.081, -1.08		
		Training 1	Congruent	661(153)	.847, -.022		
			Incongruent	656(174)	.863, .186		
		Assessment 1	Congruent	636(138)	.481, -.540		
			Incongruent	635(131)	.472, -.519		
		Training 2	Congruent	612(129)	.947, .766		
			Incongruent	607(140)	.777, .058		
		Assessment 2	Congruent	608(137)	1.39, 2.73		
			Incongruent	608(134)	1.63, 3.82		
		Control ( <i>n</i> = 51)		Baseline	Congruent	508(54.4)	1.24, 4.45
					Incongruent	505(52.7)	.711, 1.19
Training 1	Congruent			507(47.6)	.523, .793		
	Incongruent			503(45.1)	-.165, .258		
Assessment 1	Congruent			505(48.9)	.634, 2.54		
	Incongruent			512(48.3)	1.10, 3.95		
Training 2	Congruent			503(48.0)	1.07, 2.85		
	Incongruent			497(58.9)	.680, 2.00		
Assessment 2	Congruent			515(52.0)	.022, .448		
	Incongruent			506(505)	.146, .660		

*Note: M(SD) = Mean reaction times (standard deviations).*

*The distribution of the scores were measured with Skewness (S) and Kurtosis (K).*

*The standard errors of the Skewness was between .333 and .597, the standard errors of the Kurtosis was between .656 and 1.15.*

Table 3

*Range, Mean Scores (M), Standard Deviations (SD) and the Distribution of Scores the Valence Ratings Pre- and Post-Experiment of all Shapes in Chapter 1*

	Shape	Pre-experiment		Post-experiment	
		Range, M (SD)	S, K	Range, M (SD)	S, K
Control group	Circle	29-100, 72.8 (18.1)	-156, -.826	4-100, 60.8 (23.0)	-.433, -.050
	Triangle	25-100, 61.5 (20.3)	.065, -.726	3-100, 56.5 (21.4)	-.032, -.292
	Diamond	23-100, 70.7 (15.0)	-.945, 1.19	10-100, 64.4 (21.9)	-.511, -.587
	Square	12-100, 62.8 (21.2)	-.271, -.010	7-100, 58.2 (21.7)	-.167, -.102
Experiment 1	Circle	37-100, 74.5 (18.0)	-.533, -1.07	11-100, 65.3 (22.4)	-.769, .228
	Triangle	16-100, 64.6 (17.6)	-.549, .436	2-100, 55.7 (23.9)	-.575, -.287
	Diamond	24-100, 69.8 (16.4)	-.267, .218	29-100, 68.2 (17.7)	-.440, -.257
	Square	15-100, 61.6 (22.4)	-.429, -.547	8-100, 60.8 (20.4)	-.224, .057
Experiment 2	Circle	38-100, 76.7 (17.3)	-.615, -.517	28-100, 67.1 (19.0)	-.283, -.532
	Triangle	25-100, 64.5 (19.1)	-.626, -.468	20-100, 62.5 (21.3)	-.500, -.494
	Diamond	27-100, 69.0 (17.6)	-.168, -.347	0-100, 63.4 (22.5)	-.746, .531
	Square	30-100, 71.4 (18.0)	-.125, -.693	33-100, 67.3 (16.6)	.350, -.709

*Note: The distribution was measured with Skewness (S) and Kurtosis (K).*

*The standard error of the skewness was between .333 and .350, the standard error of the Kurtosis was between .656 and .688.*

Table 4

*Split Half Reliability of the Dot-Probe Task with 5000 Random Iterations in Chapter 1.*

Experiment	Group	Phase	Awareness	Mean split half (95%CI)	Spearman-Brown (95%CI)
Experiment 1	Experimental	Baseline	Total ( $n = 47$ )	-0.14 (-0.35, 0.10)	-0.36 (-1.06, 0.19)
			Aware ( $n = 22$ )	0.12 (-0.20, 0.46)	0.17 (-0.52, 0.63)
			Not aware ( $n = 25$ )	-0.44 (-0.66, -0.16)	-1.79 (-3.80, -1.38)
		Assessment 1	Total ( $n = 47$ )	-.016 (-0.14, 0.09)	-0.44 (-1.38, 0.17)
			Aware ( $n = 22$ )	-0.27 (-0.60, 0.10)	-0.93 (-3.01, 0.18)
			Not aware ( $n = 25$ )	-0.02 (-0.31, 0.30)	-0.10 (-0.89, 0.47)
		Assessment 2	Total ( $n = 47$ )	0.08 (-0.13, 0.31)	0.13 (-0.32, 0.47)
			Aware ( $n = 22$ )	0.35 (0.06, 0.62)	-0.85 (-2.20, 0.10)
			Not aware ( $n = 25$ )	-.027 (-0.52, 0.05)	0.50 (0.11, 0.76)
			Control	Total ( $n = 51$ )	0.04 (-0.18, 0.26)
Experiment 2	Experimental	Assessment 1	Total ( $n = 40$ )	-0.01 (-0.22, 0.23)	-0.04 (-0.55, 0.38)
			Aware ( $n = 23$ )	0.11 (-0.18, 0.44)	0.16 (-0.44, 0.61)
			Not aware ( $n = 17$ )	-0.16 (-0.47, 0.25)	-0.49 (-1.77, 0.40)
		Assessment 2	Total ( $n = 40$ )	-0.09 (-0.31, 0.15)	-0.24 (-0.91, 0.27)
			Aware ( $n = 23$ )	-0.08 (-0.37, 0.26)	-0.25 (-1.20, 0.41)
			Not aware ( $n = 17$ )	-0.10 (-0.43, 0.32)	-0.32 (-1.52, 0.48)
Experiment 3	Experimental	Assessment 1	Total ( $n = 46$ )	0.24 (0.00, 0.46)	0.37 (0.00, 0.63)
			Aware ( $n = 14$ )	0.37 (-0.01, 0.72)	0.51 (-0.02, 0.84)
			Not aware ( $n = 31$ )	0.16 (-0.15, 0.45)	0.24 (-0.35, 0.62)
		Assessment 2	Total ( $n = 46$ )	-0.16 (-0.39, 0.09)	-0.44 (-1.27, 0.17)
			Aware ( $n = 14$ )	-0.12 (-0.50, 0.35)	-0.42 (-1.98, 0.52)
			Not aware ( $n = 31$ )	-0.14 (-0.42, 0.19)	-0.40 (-1.45, 0.32)

*Note.* The R package 'splithalf' version 0.3.1 was used to calculate the above split half reliabilities of the Dot-Probe task with function 'splithalf\_diff' (Parsons, 2018). The following additional arguments were used: *halftype* = "random", *no.iterations* = 5000, *RTmintrim* = 100, *RTmaxtrim* = 2500.

### Chapter 3

The first three experiments in this thesis investigated a working template wherein the dot-probe task acquires and changes attention bias by using different stimulus-probe contingencies in an attention bias modification (ABM) paradigm. Non-emotional stimuli were used to establish this template without the interference of individual differences related to emotional stimuli. The findings of the dot-probe task employed with non-emotional stimuli in the previous three experiments alluded to the possibility that individual differences, which are not related to emotion, also appear to influence attention bias acquisition and change. This was revealed by the apparent fragility of the stimulus-probe associative learning mechanism that was demonstrated by the inconsistent results found in the previous experiments. One individual difference that explained variance in attention bias acquisition was contingency awareness. Attention bias to congruent non-emotional stimuli was acquired during training in participants, who reported awareness of a stimulus-probe contingency. No attention bias was acquired in those who did not report awareness of this contingency. This finding suggests that contingency awareness is necessary for attention bias change to occur in a dot-probe task that used non-emotional stimuli. However, not all variance in the results were explained by contingency awareness, for instance, it is still unclear why an attention bias was induced in the second and not in the initial contingency training or why the acquired attention bias was no longer evident in the post-training assessment. Therefore, it is likely that other individual differences or task parameters are important in achieving attention bias acquisition with non-emotional stimuli.

The following two experiments incorporated emotion into the design. This was done by including emotional stimuli in the dot-probe task. The emotional stimuli used in the current experiment in the dot-probe task were angry and neutral facial expressions. To control for other biases in facial recognition, like race (Meissner & Brigham, 2001), age (Anastasi & Rhodes, 2006), and gender biases (Herlitz & Rehnman, 2008), only middle-aged male Caucasian faces were chosen. These stimuli increase the applicability of the findings in a clinical setting. However, the inclusion of emotion into the design also increases the number of individual differences that can confound the effect of stimulus-probe associations on attention bias acquisition and change using the dot-probe task.

The main individual difference that influences the relation between emotion and attention bias acquisition and change is psychopathology. That is, greater attention bias towards emotional stimuli is found in individuals with higher than those with lower or no pathology symptomology (e.g., Bantini et al., 2016; Bar-Haim et al., 2007; MacLeod et al., 1986). Furthermore, this difference in magnitude of the pre-existing bias has also shown to affect the efficacy of ABM training. There seems to be a positive association between magnitude of pre-existing attention bias and magnitude of attention bias change when trained away from threatening stimuli (Mogoşe et al., 2014; Price et al., 2016). This suggests that ABM is most effective in changing negative attention bias with participants who have a greater pre-existing negative attention bias, which is mostly found in individuals with higher levels of psychopathology.

To assess the effect of individual differences in psychopathology and contingency awareness on the acquisition and change of attention bias, measures of social anxiety and contingency awareness were included at the start and end of the experiment, respectively. Levels of social anxiety were measured as the relevance of the stimuli content is important in the existence of attention bias related to psychopathology (Pergamin-Hight et al., 2015). Attentional biases towards angry faces have been shown to be an important factor in the aetiology and maintenance of social anxiety disorder (Bar-Haim et al., 2007; Wong & Rapee, 2016), which is one of the most prevalent of all anxiety disorders (Kessler, Chiu, Demler, & Walters, 2005). Furthermore, given that social anxiety is the most resistant to existing treatments (Wong & Rapee, 2016), research into a different type of social anxiety disorder treatments (i.e., ABM) may be particularly relevant.

The objectives of the two experiments discussed in this chapter involved establishing a working template wherein the dot-probe task could be used to successfully assess and train (pre-existing) attention bias towards emotional stimuli. The current experiment consisted of five phases (similar to the three experiments described in Chapter 2). These were the baseline assessment, the first training (*training 1*), the first post-training assessment (*assessment 1*), the second (reversed contingency) training (*training 2*), and finally, a post-training assessment (*assessment 2*). With this design it was assessed whether participants had a pre-existent bias towards angry faces at baseline, whether selective attention can be trained towards emotional or neutral stimuli, and whether an acquired bias could be extinguished or

reversed through exposure to a subsequently reversed training contingency. Especially, compared to participants in the no-training control group, those trained to attend to angry faces (in the initial or reversed training) would show an attention bias to angry faces in the within-training assessment, while those trained to attend to neutral faces (in the initial or reversed training) would show an attention bias to neutral faces in the within-training assessment. The second objective was to assess whether individual differences in contingency awareness and social anxiety were associated with pre-existing negative attention bias at baseline, attention bias acquisition within the initial and reverse training and the magnitude of attention bias change from pre- to post-training.

It was hypothesised that selective attention would be biased towards angry faces at baseline and the magnitude of the pre-existing bias would be positively associated with levels of social anxiety. Furthermore, it was hypothesised that levels of social anxiety and pre-existing attention bias would be positively associated with magnitude of attention bias acquisition and change. Next, it was hypothesised that contingency awareness would be a prerequisite for attention bias acquisition, which would occur through stimulus-probe contingency learning. In other words, only those aware of the stimulus-probe contingency would show quicker responding to the probe preceded by predictive stimuli relative to the probe that was preceded by unpredictable stimuli during training. Lastly, if consistent with the previous experiments, an acquired pattern of selective attention would no longer persist when the contingency is not predictive (i.e., in the post-training assessments). Hence, we would expect to see evidence of bias acquisition in the within-training assessment, but this attention bias change would not be maintained in the post-training assessment. However, if the introduction of emotional stimuli aids the transfer of acquired attention bias from training to post-training assessment, it would be expected to see evidence of attention bias acquisition and change in the within-training and post-training assessment phases of the ABM design.

## **Experiment 4**

### **Methodology**

#### **Study Design**

Participants received either non-contingency control training or they were either trained to attend to angry faces in the first training and to neutral faces in the second training (angry-neutral condition [labelled as AN]) or reversed (neutral-angry

condition [labelled as NA]). The order of the contingency in training in the experimental group was counterbalanced. The study design was a mixed factorial design, with one between-group and two within-group factors. The two within factors were the order of contingency delivered (initial vs reversed), and the different assessment points (within-training and post-training). The between-group factor was Condition, where the two active training conditions of the experimental group were compared with a control group. The baseline assessment was analysed separately to test the hypothesis that a pre-existing attention bias to emotional stimuli was present at baseline, especially for those high in social anxiety.

### **Participants**

One hundred and twenty-five Mechanical Turk workers participated in the experiment. Thirty participants who made more than the pre-determined 30% of errors and one participant who attempted the task twice were deleted from the sample, resulting in a total sample of 94 who made on average 12% errors ( $SD = 6.06$ , range: 2.14 - 28.0). Participants ( $M_{age} = 32.5$ ,  $SD = 6.60$ , range: 22 – 49, 33% female) were randomly assigned to two experimental groups ( $n = 59$  [AN:  $n = 33$ ; NA:  $n = 26$ ]) or the control group ( $n = 33$ ).

### **Procedure**

Participants started with a screen calibration procedure to ensure consistency in stimulus parameters across screen sizes and resolutions. First, participants completed 39 anxiety-related questions from the Social Interaction Anxiety scale and the Social Phobia Scrutiny Scale (Mattick & Clarke, 1998). This was followed by 8 practice and 400 experimental trials of the dot-probe task. The experimental group completed a baseline assessment, a training, a post-training assessment, the reversed contingency training, and a post-assessment. The control group completed the same number of non-predictive assessment trials. The experiment ended with the contingency awareness check and demographic questions. The whole procedure was programmed in Inquisit 4 (2015) and hosted online via TurkPrime (Litman et al., 2017). It took participants approximately 35 minutes to complete the experiment and they were reimbursed with 5 USD. The protocol was approved by the Human Research Ethics Committee at Curtin University.

## Materials

### Stimuli Used in Dot-Probe Task

Compared to the non-emotional shapes used in the dot-probe task described in Chapter 2, eight Caucasian male models were selected from the NimStim database (Tottenham et al., 2009), each depicting a neutral and an angry expression (closed mouth). These stimuli were sized at 300x385pixels.

### Dot-Probe Task

The same dot-probe task was used as described in Experiment 3 (see Chapter 2). Every trial would start with a 500ms presentation of a fixation cross in the middle of the screen, followed by the two stimuli presented next to each other for 500ms. The two stimuli were separated on the screen by 80mm. Then, a probe (4mm in size) would be presented in the locus of one of the two stimuli. The probe would disappear after a response was made or after 500ms. This limitation in probe duration was included in the previous experiment to increase reliance on the stimuli to predict the location of the probe. It was decided not to change this task parameter, so that the experiments were consistent and the effect of the inclusion of emotional stimuli can be assessed. Participants were instructed to respond as quickly as possible, without making mistakes, to the orientation of the probe (either horizontally like ‘.’ or vertically like ‘:’). Similar to the dot-probe task described in Chapter 2, the experiment consisted of assessment and training phases. The assessment procedure consisted of 80 trials with a 50% stimulus-probe contingency, that is, the stimulus type did not predict the location of the probe. The training procedure consisted of 160 trials with a 95% stimulus-probe contingency, that is, on 95% of the trials, the probe followed the same stimulus ( $n_{\text{trials}} = 152$ ; labelled as *congruent trials*) and on 5% of the trials, the probe followed the other stimulus ( $n_{\text{trials}} = 8$ ; labelled as *incongruent trials*). The order in which the training contingencies were delivered was counterbalanced across participants such that half were first trained towards angry and away from neutral faces (AN condition) while the remainder were first trained towards neutral and away from angry faces (NA condition).

### Contingency Awareness Check

The contingency awareness measure was the same as used in the previous experiments. Three questions were included at the end of the experiment to assess explicit awareness of any contingency: “Did you notice any regularities during the

computer task?”. Answer options were yes or no, if answered yes, this was followed up with the open ended question: “What did you notice?”. Lastly, a multiple-choice question was asked: “Did the dots follow more after a certain shape?”, six contingency options were given where participants could choose from (e.g., “No, the dots were presented equally often after both shapes”). As described in the previous chapter, participants of the experimental group were dichotomised into an aware or not aware category. Participants who selected any option indicating that there may have been a contingency involved were categorised as aware, even if they got it wrong, whereas the remaining were categorised as unaware. To reiterate, this liberal criterion was adopted because the contingency awareness check came at the end of the experiment, after multiple contingency changes. It was to take into account that it was hard for participants to remember exactly what happened throughout the procedure.

### **Strategy**

The same open-ended question (“Did you use a certain strategy?”) was included as the previous experiment to assess the strategy used by the participant to perform the dot-probe task.

### **Social Interaction Anxiety Scale**

Social interaction anxiety was measured with the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998). The SIAS consists of 19 items (e.g.: "I have difficulty making eye-contact with others") wherein scores ranged from 0 (not at all) to 4 (extremely). After the reverse scoring of two items, the possible range of scores was between 0 and 76. The internal consistency of the scale was excellent ( $\alpha = .965$ ).

### **Social Phobia Scrutiny Fear**

Social phobia scrutiny fear was measured with the Social Phobia Scrutiny (SPS) scale (Mattick & Clarke, 1998). The SPS consists of 20 items (e.g.: "I feel self-conscious if I have to enter a room where others are already seated") wherein scores ranged from 0 (not at all) to 4 (extremely). The possible range of scores was between 0 and 80. The internal consistency of the scale was excellent ( $\alpha = .944$ ).

### **Data Preparation and Statistical Analyses**

Analyses, statistical outcomes, and errors were based on the same criteria as described in the methodology of Experiment 3 (see Chapter 2). The mean RTs for each trial type per Condition are reported in the Appendix Table 10 at the end of this

chapter. Out of these mean RTs, bias index scores (BIS) were calculated, where the overall mean RTs of trials where the probe was placed in the same location as the angry face (labelled as *angry-trial*) were subtracted from the overall mean RTs of trials where the probe was placed in the same location as the neutral face (labelled as *neutral-trial*). A positive BIS indicated an attention bias towards angry faces, whereas a negative BIS indicated an attention bias towards neutral faces. Two participants had extreme outlier scores (a value more than 3 times the interquartile range) in the BIS measured at baseline and were excluded from the following analysis. The mean BIS measured at baseline was compared to zero in a one-sample t-test, used to test whether attention was biased at baseline towards angry compared to neutral faces. One other extreme outlier was detected in the first training phase and was excluded from the analysis that investigated whether attention bias was acquired and changed as a result of the stimulus-probe contingencies employed in the ABM paradigm. In this analysis, the mean BIS were subjected to a 2 x 2 x 3 (Contingency [initial vs reversed] x (Assessment [within-training vs post-training] x (Condition [AN vs NA vs control])) repeated measures mixed-design analyses of variance (ANOVA).

There were no extreme outliers in the SPS and SIAS scores, hence no participants were excluded based on this criterion. Analyses were conducted for the two active training conditions in the experimental group, since the control group did not receive any training. Firstly, attention bias change scores were calculated for attention bias change from baseline to the first post-training assessment ( $AB_{\text{Change1}}$ ), and bias change from the first to the second post-training assessment ( $AB_{\text{Change2}}$ ). These change scores were calculated by subtracting the BIS in the post-training assessment from the BIS in the pre-training assessment. Secondly, it was examined whether there was an association between social anxiety and an elevated degree of attention bias to angry faces at baseline, greater attention bias acquisition within training 1 and 2, as well as greater malleability of attention bias change as indicated by the  $AB_{\text{change1}}$  and  $AB_{\text{Change2}}$  scores. Pearson's correlations were computed between the SIAS and SPS sum scores and the BIS in all phases per active training condition (Bonferroni corrected  $p < .010$ ). Thirdly, to examine whether the magnitude of pre-existing bias was associated with attention bias change away from threat, Pearson correlations were calculated between BIS measured at baseline and in training phases where participants were trained to attend to neutral stimuli. Thus, pre-existing bias

was correlated with the BIS measured in training 1 and  $AB_{\text{Change1}}$  in the NA condition and with the BIS measured in training 2 and  $AB_{\text{Change2}}$  in the AN condition. However, given that the  $AB_{\text{Change1}}$  include the BIS from the baseline phase in its calculation, a high correlation ( $> .850$ ) would indicate multicollinearity, not a true effect.

The  $2 \times 2 \times 2$  (Contingency [initial vs reversed])  $\times$  (Assessment [within-training vs post-training])  $\times$  (Awareness [aware vs not aware]) mixed-design analyses of variance (ANOVA) was not analysed as only eight participants in the experimental group ( $< 15\%$ ) were categorised as aware.

## Results

### Attention Bias at Baseline, Training and Assessment Phases

A one-sample t-test showed that there was no general attention bias towards angry, relative to neutral facial expressions at baseline ( $M = -10.3$ ,  $SD = 77.2$ ),  $t(89) = -1.27$ ,  $p = .209$ ,  $95\%CI(-26.5, 5.87)$ . The mean emotional bias index scores in each experimental phase are shown in in Figure 7. The ANOVA, which tested the rest of the ABM paradigm, resulted in a marginal significant effect between Contingency and Assessment,  $F(1,87) = 3.03$ ,  $p = .085$ ,  $\eta^2 = .034$ . Post-hoc pair-wise comparisons showed that there was no significant difference between the within-training and post-training assessments points in the initial contingency,  $t(89) = .918$ ,  $p = .361$ ,  $95\%CI(-10.6, 28.6)$ ,  $d = 0.15$ , however, marginally in the reversed contingency,  $t(89) = 1.90$ ,  $p = .060$ ,  $95\%CI(-.663, 30.3)$ ,  $d = 0.27$ . All other effects in the omnibus ANOVA were not significant,  $F < .838$ ,  $p > .363$ ,  $\eta^2 < .010$ . The stimulus-probe associations do not seem to influence attention bias acquisition or change.

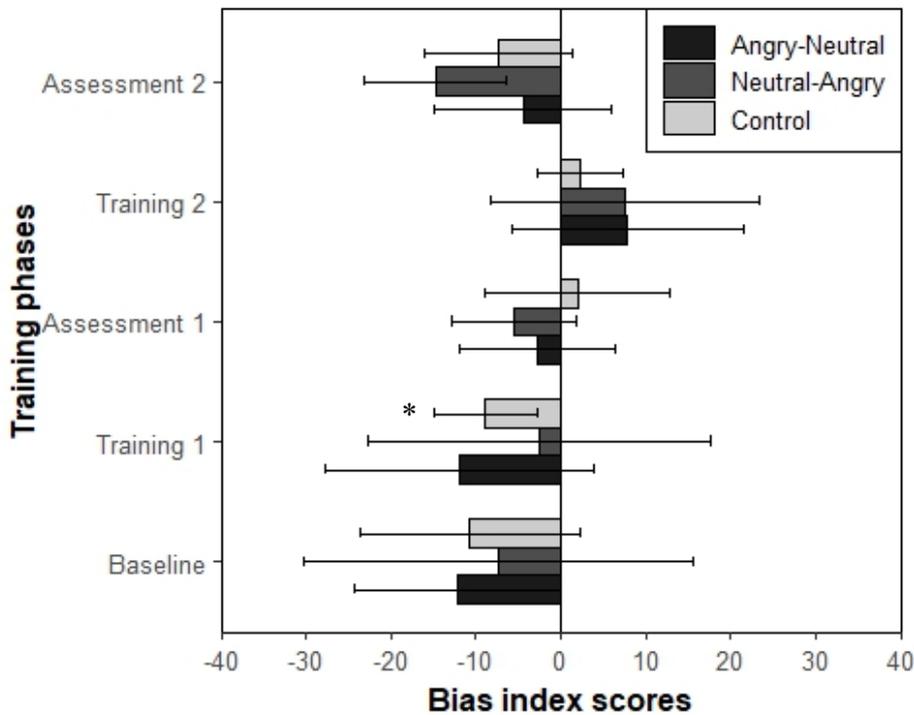


Figure 7. Mean Bias Index Scores in the Experimental and Control groups of Experiment 4 as a Function of Phase.

Negative scores indicate an attention bias towards the neutral faces, whereas positive scores indicate an attention bias towards angry faces. Error bars represent standard error of the mean.

\*  $p < .050$  (different from zero).

**Social Anxiety and its Association with Pre-Existing Attention Bias at Baseline**

A score greater than 22 and 18 is considered the clinical cut-off point for the SIAS and SPS, respectively. On the SIAS, 49% of participants were above the clinical cut-off point in the AN condition, compared to 35% in the NA, and 67% in the control condition, whereas, on the SPS, these percentages were 33%, 23%, and 58%, respectively. One-way ANOVAs indicated that there were significant differences between conditions on these social anxiety scores as shown in Table 2, SIAS:  $F(2,89) = 4.48, p = .014, \eta^2 = .091$ , and SPS:  $F(2,89) = 3.11, p = .049, \eta^2 = .065$ . Post-hoc pair-wise comparisons between the three conditions revealed that in both social anxiety measures, significantly lower social anxiety scores were found in the NA condition than in the control condition, for both measures  $t > 2.49, p < .043, 95\%CI(.207, 18.9), d > 0.70$ . No other significant differences were found in social anxiety scores, all other comparisons,  $t < 1.44, p > .460, 95\%CI(-3.62, 14.0), d < 0.33$  (Bonferroni corrected). Table 5 presents the descriptive statistics of the self-reported social anxiety measures.

Table 5.  
*Descriptive Statistics of the Self-Reported Social Anxiety Measures*

Condition		Range	<i>M(SD)</i>	Distribution <i>S, K</i>
Angry-Neutral ( <i>n</i> = 33)	SIAS	0 - 70	26.1(18.2)	.552, -.467
	SPS	0 - 53	17.7(15.6)	1.03, .112
Neutral-Angry ( <i>n</i> = 26)	SIAS	0 - 63	18.9(15.1)	.975, .465
	SPS	0 - 42	12.5(10.5)	1.22, 1.46
Control ( <i>n</i> = 33)	SIAS	0 - 62	32.8(19.0)	-.400, .409
	SPS	0 - 53	22.1(16.3)	.354, -.854

*Note: SIAS = social interaction anxiety scale; SPS = social phobia scale; M(SD) = Mean (standard deviation). Distribution is represented with Skewness (S) and Kurtosis (K), the standard errors of the distribution measures were between .409 and .798.*

Social anxiety was not associated with BIS assessed at baseline, the correlations were not significant, both  $r < -.113$ ,  $p > .291$  (see Figure 8).

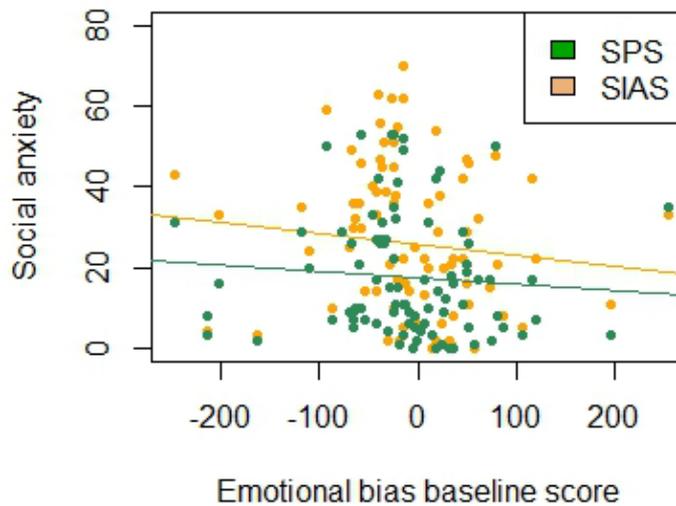


Figure 8. Association between Social Anxiety and Emotional Bias Scores Measured at Baseline for Each Condition in Experiment 4. The solid lines represent the linear line of best fit.

### **Social Anxiety and its Association with Attention Bias Acquisition and Change**

After Bonferroni correction, none of the correlations between the SIAS and SPS scores and the BIS measured within the dot-probe training assessments or as a change score were significant in the active training conditions, all  $r < .356$ ,  $p > .042$  (see Figure 9 and 10).

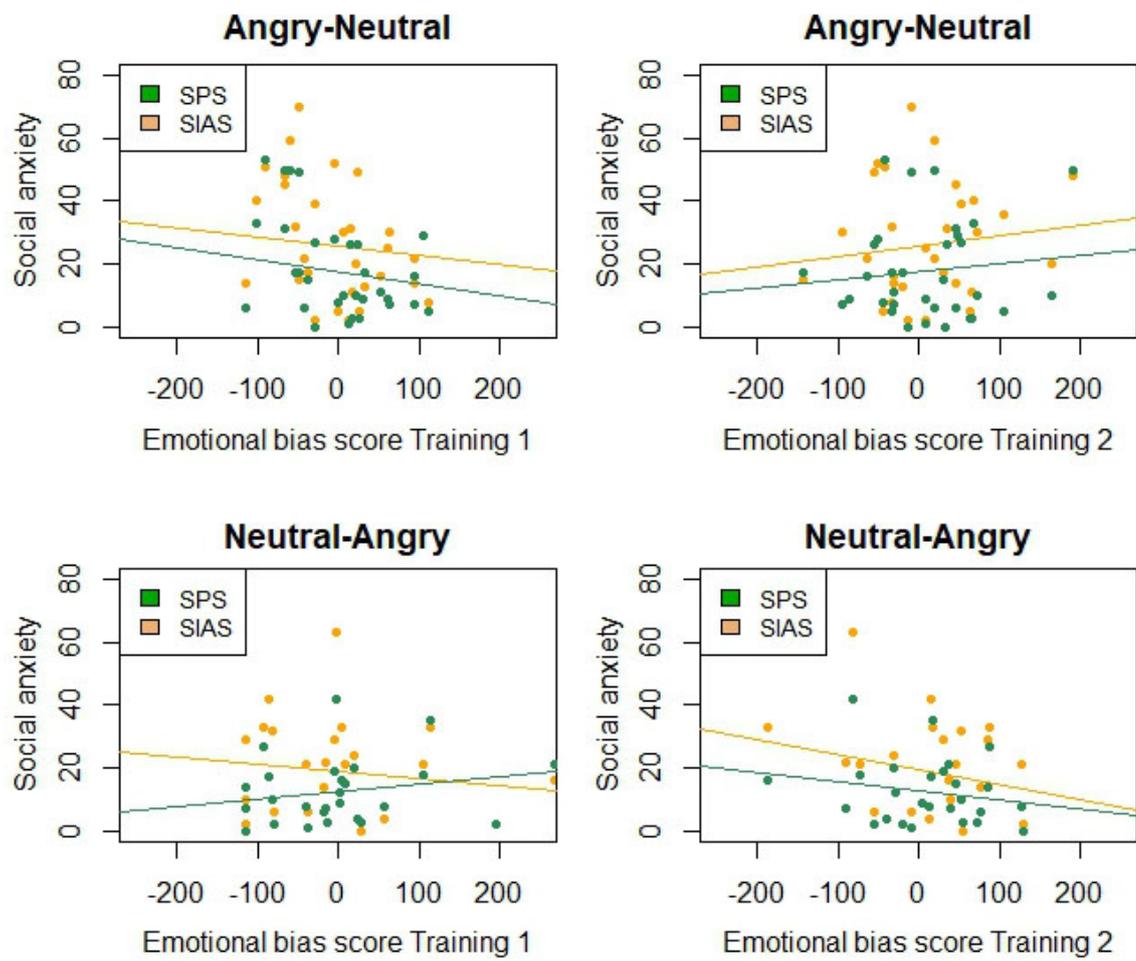


Figure 9. Associations between Social Anxiety and Emotional Bias Index Scores Measured within Each Training Pre- to Post-Training for Each Active Training Condition in Experiment 4. The solid lines represent the linear line of best fit.

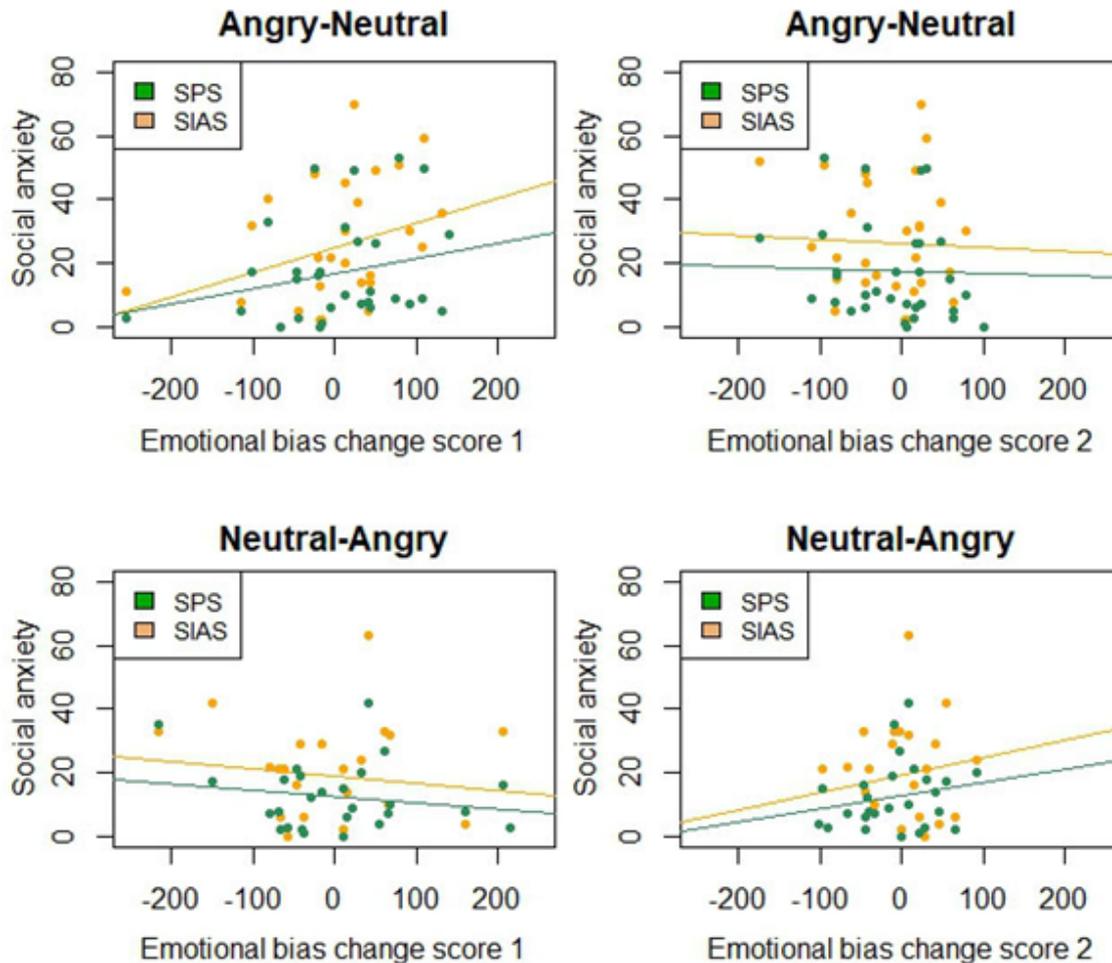


Figure 10. Associations between Social Anxiety and Emotional Bias Index Scores Measured as an Attention Bias Change Score Pre- to Post-Training for Each Active Training Condition in Experiment 4. The solid lines represent the linear line of best fit.

The hypotheses, which stated that higher levels of social anxiety were related to pre-existing negative attention bias and increased magnitude of attention bias change were not supported.

### Pre-Existing Attention Bias and its Association with Attention Bias Acquisition and Change

There were no significant correlation in the NA training condition between the BIS assessed at baseline and the BIS assessed within training 1,  $r(24) = .189, p = .354$  or between the BIS assessed at baseline and BIS within training 2 in the AN training condition,  $r(28) = .095, p = .617$  (see Figure 11). The BIS assessed at baseline correlated significantly with the  $AB_{\text{Change1}}$  in the NA training condition,  $r(24) = -.948, p < .001$ . However, given that the  $AB_{\text{Change1}}$  calculation included the BIS from the baseline phase, this high correlation indicates multicollinearity ( $> .850$ ), not

a true effect. The BIS assessed at baseline did not correlate with the  $AB_{\text{Change2}}$  in the AN training condition,  $r(28) = -.067, p = .724$ .

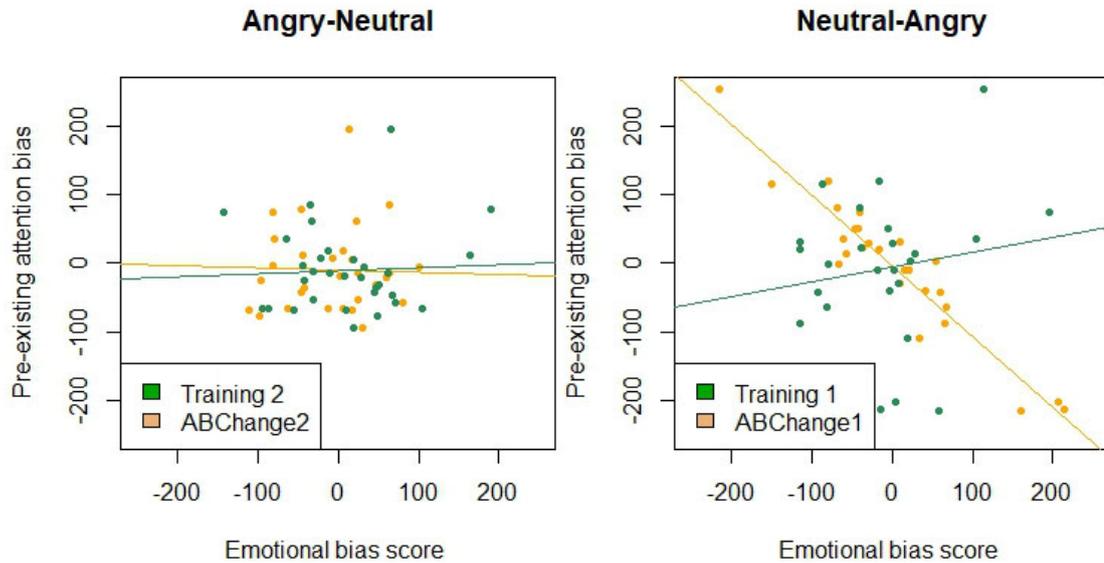


Figure 11. Association between Pre-Existing Attention Bias and Emotional Bias Index Scores Measured within and Pre- to Post-Training away from Threat for Each Condition in Experiment 4. The solid lines represent the linear line of best fit.

These results suggest that the magnitude of the pre-existing bias was not associated with attention bias acquisition or change when participants were trained away from threat.

### Strategies Used to Perform the Dot-Probe Task

Qualitative responses were categorised into four themes and are reported in Table 6. These were: (1) No strategy used (e.g., “No”); (2) Focused on the probes (e.g., “I blocked out the faces as best as possible and focused on the dots”); (3) Focused on certain location of the screen (e.g., “I focused on the left face to watch for dots, and if they weren't there I switched my eyes over to the right side quickly”); (4) Faces predicted the probe (e.g., “I would look as quick as possible and tried to see if certain faces would bring certain dot patterns”). In addition, some participants ( $n = 3$ ) explicitly reported that the task was too difficult to perform (e.g., “No, this was so very difficult!”).

Table 6.  
*Strategies Used to Perform the Dot-Probe Task in Each Condition*

Themes	Angry-Neutral	Neutral-Angry	Control
No strategy used	$n = 14$ (42%)	$n = 9$ (35%)	$n = 14$ (42%)
Focused on the probes	$n = 9$ (27%)	$n = 10$ (38%)	$n = 10$ (30%)
Focused on certain location of the screen	$n = 8$ (24%)	$n = 6$ (23%)	$n = 8$ (24%)
Shape predicted the probe	$n = 2$ (6%)	$n = 1$ (4%)	$n = 1$ (3%)

The type of strategy used did not differ per training condition,  $X^2(6) = 1.27$ ,  $p = .974$ ,  $\phi = .117$  and are not further analysed because of the small numbers.

### Discussion

The aim of this experiment was to test whether predictive and non-predictive stimulus-probe associations were adequate in inducing, changing and assessing (pre-existing) attention bias in participants. Compared to the previous experiments that used non-emotional shapes (circles and triangles), this experiment used emotional stimuli depicting angry and neutral faces. The results showed that attention bias was not acquired or changed through the stimulus-probe contingencies used in the emotional dot-probe task. No attention bias was induced as a result of the 95% stimulus-probe contingency training and there was no attention bias evident in the assessment phase post-training. The principles of associative learning theories may predict the lack of contingency training found in this experiment. These principles state that attention paid to the stimulus, which preceded the probe, increases the strength of the associative connection between them (Mackintosh, 1975; Rescorla & Wagner, 1972). It is possible that not all participants paid attention to the stimulus and as a result did not learn the stimulus-probe associations. This is somewhat supported by the self-reported strategies, which showed that participants did not use any strategy to perform the dot-probe task or focused either on the probes or a certain location of the screen. Merely, an approximate of 5% of participants reported a strategy that involved the stimuli to perform the dot-probe task.

It is possible that some participants did not pay attention to the stimulus to predict the location of the probe because the task parameters of the dot-probe task were too strict. Compared to the conventional dot-probe task, which does not limit the probe duration, the probe duration in the current task was limited to 500ms. This was included to replicate the task parameters used in Experiment 3, which intended

to increase the reliance on the non-emotional stimuli to predict the probe. However, this manipulation of task parameter combined with the inclusion of emotional stimuli may have increased the difficulty level of the dot-probe task to a level that made the task too hard for participants to complete. Some participants explicitly reported, in the strategy assessment, that they had trouble carrying out the task because it was too difficult. The increase of difficulty was also represented in the increase of average RTs from Experiment 3 to Experiment 4 (See Appendix Tables 10 and 11). It is possible that the difficulty level of the dot-probe task needs to be tailored, so that participants do not ignore the stimuli that precede the probe, because the task is either too difficult or too easy to perform. Furthermore, the conventional ABM paradigm does not include a reversed training contingency. This switch in stimulus-probe contingency, in the middle of the paradigm, may hinder stimulus-probe associative learning. Therefore, to achieve stimulus-probe associative learning related to attention bias acquisition and change, it is suggested that the probe duration in the dot-probe task may need to be increased and the ABM paradigm may need to be simplified by omitting the reversed contingency phases.

The secondary objective was to examine whether individual differences in social anxiety were associated with pre-existing attention bias, and whether individual differences in social anxiety, pre-existing attention bias and contingency awareness were associated with attention bias acquisition and change. In contrast to the previous experiments that used non-emotional stimuli, individual differences in contingency awareness did not explain any variance in the lack of attention bias found throughout the ABM paradigm. Most participants reported no awareness of any contingency. Combined with the self-reported results on the strategy used, it is likely that most participants did not become aware of the contingency as they did not pay any attention to the stimulus that preceded the probe. Moreover, the previous experiments found evidence for attention bias acquisition to the congruent stimulus in those that reported awareness of the stimulus-probe association. Therefore, the lack of attention bias acquisition and change in the current experiment may be associated with the lack of participants' awareness of the stimulus-probe contingency. Furthermore, in contrast to what was hypothesised, there was no evidence of pre-existing attention bias at baseline nor was there an association between social anxiety and magnitude of pre-existing attention bias. Additionally,

there were no association between pre-existing attention bias and attention bias acquisition and change when participants were trained away from threat.

The lack of associations between individual differences in social anxiety and pre-existing attention bias is in contrast to what was hypothesised based on the attention and emotion theories discussed in Chapter 1 and previous meta-analyses conducted (e.g., Bar-Haim et al., 2007). According to Bantini et al. (2016), the common reason for this null finding is that a non-selected sample often consists of individuals with relatively homogeneous and low levels of social anxiety. However, our sample consisted of relatively high number of socially anxious individuals and there was a high variability of scores. Nonetheless, according to recent reviews, most studies that used the standard dot-probe task to assess attention bias did not find an attention bias toward threat relative to non-threat stimuli in anxious individuals at baseline (Dudeny, Sharpe, & Hunt, 2015; Mogg & Bradley, 2016; Mogg, Waters, & Bradley, 2017; Roberts, Farrell, Waters, Oar, & Ollendick, 2016; Van Bockstaele et al., 2014). Other evidence also suggests that anxious individuals do not consistently show an attention bias toward threat and sometimes show threat-avoidance or no bias at all (Cisler & Koster, 2010; Dudeny et al., 2015; Kruijt, Parsons, & Fox, 2019; Waters, Bradley, & Mogg, 2014).

Contrary to what was hypothesised, levels of social anxiety were not associated with attention bias acquisition or attention bias change. However, this may be explained by the lack of pre-existing attention bias. Studies showed that the magnitude of pre-existing attention bias was positively associated with the efficacy of ABM training away from threat (Mogoşe et al., 2014; Price et al., 2016). It may be that the association between social anxiety and attention bias acquisition and change is mediated by the existence of pre-existing attention bias. Without a pre-existing attention bias to angry faces, the stimulus-probe association in the dot-probe task may not be effective in inducing or changing attention bias. However, the possibility remains that participants did not attend to the face stimuli in the dot-probe task to predict the location of the probe. Without attention paid to the stimuli, the dot-probe task cannot assess an existing attention bias, nor induce or change it. It is possible that the task parameters used with non-emotional stimuli, like the limited probe duration of 500ms, were too strict when assessing an attention bias in emotional stimuli. The task may be too difficult (i.e., too fast) for participants to pay attention to the stimuli, which predict the location of the probe.

To summarise, it was found that attention bias was not acquired or changed in the training and assessment phases when different stimulus-probe contingencies were employed during those phases. In other words, participants were not quicker to respond to the congruent stimuli that predicted the location of the probe compared to the incongruent stimuli that were unpredictable of the probe's location. There was a lack of contingency awareness, which may be the result of the lack of attention to the stimulus or due to the increased difficulty of the task. Individual differences in social anxiety did not explain any variance in pre-existing attention bias, neither did they explain any variance in the attention bias within training or in attention bias change measured pre-to post-training. It is suggested that a decrease in the difficulty level of the dot-probe task and ABM paradigm would facilitate stimulus-probe associative learning and subsequently lead to attention bias acquisition and change.

### **Experiment 5**

Experiment 5 was designed with the aim of decreasing the difficulty level of the procedure and assessing whether this manipulation would increase stimulus-probe contingency learning and awareness in participants completing the dot-probe task. As a result, it was hypothesised that participants would acquire an attention bias during training and a change in attention bias from pre- to post-training. To decrease the difficulty level of the procedure, the ABM paradigm was simplified by eliminating the reversed contingency training and post-training assessment. Therefore, the ABM paradigm consisted of a baseline assessment, a training and a post-training assessment phase, which resembles a conventional ABM paradigm. Apart from testing whether the change in task parameters would facilitate contingency learning and awareness and so, attention bias acquisition and change, this experiment also replicated a standard ABM study, which is highly valued (e.g., Simons, 2014). Furthermore, the exposure time of the probe in the dot-probe task was increased from 500ms to 700ms. The 500ms probe duration limitation was included in the previous procedure to replicate the procedure of Experiment 3. Initially, the limitation in probe duration was included to increase reliance on the stimuli to predict the location of the probe. However, the lack of results found in Experiment 4 may suggest that the dot-probe task was too difficult and hindered stimulus-probe associative learning. Furthermore, participants may not have paid attention to the stimulus and, therefore, no stimulus-probe association was established. This may have caused the lack of attention bias acquisition and change

throughout the ABM procedure as well as the lack in associations between these dependent variables and individual differences in emotional vulnerability and pre-existing bias.

In the previous experiment, no association between magnitude of pre-existing attention bias and levels of social anxiety were found at baseline. These findings did not support the attention and emotion theories discussed in Chapter 1 and previous meta-analyses (e.g., Bar-Haim et al., 2007). To investigate whether emotion vulnerability is associated with attention bias or attention bias acquisition and change, levels of trait and state anxiety were assessed in addition to the measures of social anxiety. Trait and state anxiety are reliably measured with the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The STAI assesses whether individuals feel anxious in that moment (STAI-state) or in general (STAI-trait). This measure is one of the best-established and most widely used psychometric instruments for assessing anxiety vulnerability. Since the sample is non-selected, it was investigated whether the inclusion of the STAI could find and association between attention bias at baseline and different levels of anxiety vulnerable as previously found in Mogg, Bradley, and Hallowell (1994).

In addition to contingency awareness and the anxiety measures, individual differences in attention control were assessed to investigate whether individual differences in attention control are associated with stimulus-probe associative learning. Research has shown that cognitive control and cognitive biases are associated mechanisms of attention and emotional vulnerability (Basanovic et al., 2017; Chen, Clarke, Watson, MacLeod, & Guastella, 2014; Everaert et al., 2017; Sanchez et al., 2015; Taylor et al., 2016). For instance, Everaert et al. (2017) found that deficient inhibitory control over negative stimuli was related to negative attention bias, which in turn predicted an interpretation bias as well as subsequently depressive symptoms. Additionally, studies have found that attention control predicts the magnitude of attention bias change in response to ABM (Basanovic et al., 2017; Chen et al., 2014). Basanovic et al. (2017) demonstrated that individual differences in control of attentional inhibition were positively associated with individual differences in the magnitude of attentional bias change.

The same attention control task was used in the current experiment as described in Basanovic et al. (2017). It was explored whether individual differences in attention control can explain variance in pre-existing attention bias, attention bias

acquisition and change as well as contingency awareness. In particular, those with impaired (compared to higher) attentional control of selectivity and inhibition may have a pre-existing attention bias at baseline, whereas, individuals with higher (compared to lower) levels will show increased learning of the contingency employed in training and an increased awareness of this contingency. Furthermore, attention bias may be more malleable in individuals with higher (compared to lower) levels of attention control, such that they will show increased magnitude of attention bias change from pre-to post-training.

In sum, it was tested whether a change in task parameters and study design would decrease the difficulty level of the dot-probe task and ABM procedure and facilitate contingency learning and awareness in emotional stimuli. As a result, attention bias could successfully be acquired and changed using the dot-probe task. It was hypothesised that the increased probe duration and the exclusion of the reversed training and post-training assessment would facilitate attention bias acquisition within training and attention bias change from pre-to post-training assessment. In particular, those trained to attend to angry faces would show an attention bias to angry faces in the within-training and post-training assessment, while those trained to attend to neutral faces would show an attention bias to neutral faces in the within-training and post-training assessment. No attention bias acquisition and change was hypothesised for those in the no-training control group. However, if consistent with the previous non-emotional experiments (described in Chapter 2), an acquired pattern of selective attention during training will no longer persist when the contingency is not predictive (i.e., in the post-training assessments). Furthermore, it was hypothesised that individuals with high levels of state, trait and social anxiety would show a greater pre-existing attention bias towards angry faces than neutral faces at baseline compared to those with low levels of the same constructs. Moreover, it was hypothesised that anxiety vulnerability was positively associated with attention bias acquisition and change. Next, it was hypothesised that individual differences in attentional control of selectivity and inhibition would be negatively associated with pre-existing attention bias and positively associated with attention bias acquisition and change. Lastly, it was hypothesised that those aware of the contingency showed higher attention control of inhibition and selection than those not aware of the contingency.

## Methodology

### Participants

Of the initial 133 MTurk workers who started the experiment online, 13 completed only the self-report measures, leaving 120 participants who made on average 20.6% of errors in the dot-probe task ( $SD = 20.9$ , range: 2.50 – 100) and on average 8.98% of errors on the attention control task ( $SD = 14.27$ , range: 1.56 – 100). Nineteen participants were deleted as they made more than the pre-determined 30% of errors in the dot-probe task ( $M = 61.3\%$ ,  $SD = 24.7$ , range: 32.3 – 100). The remaining 101 participants made on average 12.9% of errors in the dot-probe task ( $SD = 5.78$ , range: 2.50 - 30.0). The mean age of the final sample was 35.4 ( $SD = 10.6$ , range: 18 – 65), 52.5% were male.

### Procedure

Participants started with a screen calibration procedure which ensured that stimuli would be presented similarly across participants regardless of their screen size and resolution. Then, participants completed the 79 anxiety-questions from the SIAS, SPS, and STAI. This was followed by 8 practice and 400 main trials of the dot-probe task. The two experimental groups completed a baseline assessment, a training (attend-angry vs attend-neutral), and a post-assessment phase. The control group completed the same number of non-predictive assessment trials. Then, they completed the contingency awareness check and the 128 trials of the attention control assessment task. The procedure would end with five demographic questions. The whole procedure was programmed in Inquisit 4 (2015) and hosted online via Turk prime (Litman et al., 2017). It took participants approximately 35 minutes to complete the experiment and they were reimbursed with 5 USD. The Human Research Ethics Committee at Curtin University approved the protocol.

### Materials

#### Dot-Probe Task

The same dot-probe task was used as described in Experiment 4, however, the exposure time of the probe was increased from 500ms to 700ms. This task parameter was manipulated to decrease the difficulty level of the dot-probe task.

#### Self-Reported Measures

The following self-report measures were administered in addition to the measures described in Experiment 4.

### **Spielberger's State-Trait Anxiety Inventory**

State and trait anxiety was assessed pre-experiment with Spielberger's State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983). The STAI is a 40-item questionnaire that provides measures of current (state) anxiety and dispositional (trait) anxiety. The 20-item state anxiety subscale (STAI-S) asks participants to indicate the degree to which they are experiencing a variety of anxiety symptoms "right now" (e.g., "Right now, I am worried"). Whereas the 20-item trait anxiety subscale (STAI-T) asks participants to indicate the degree to which they are experiencing a variety of anxiety symptoms "in general" (e.g., "In general, I feel secure"). Answer options were provided on a 4-point Likert scale ranging from 1 (not at all) to 4 (very much so). Scores on each subscale ranged from 20 to 80, with higher scores representing higher levels of state or trait anxiety. STAI has been shown to have good reliability and validity (c.f. Grös, Antony, Simms, & McCabe, 2007).

### **Attention Control Assessment Task**

The same attention control assessment (ACA) was used as described in Basanovic et al. (2017). The stimuli used in the attentional control assessment task consisted of two shapes: a circle and a diamond. The shapes had equivalent spatial areas of 34 cm<sup>2</sup> and were represented as a white outline 5mm thick on a black background (Basanovic et al., 2017). The ACA task assesses whether participants have high attentional control of selectivity and inhibition. The level of selectivity is indicated by the cost of selecting a target that is presented in a certain shape in the presence (selectivity trial) vs absence of another shape (non-selectivity trial). The level of inhibition is indicated by the cost of selecting a target presented in the opposite (inhibition trial) or same location of a shape (non-inhibition trial; see Figure 12 for an example of each trial). The task consisted of four blocks, an inhibition, non-inhibition, selectivity block and a non-selectivity block with 32 trials in each block.

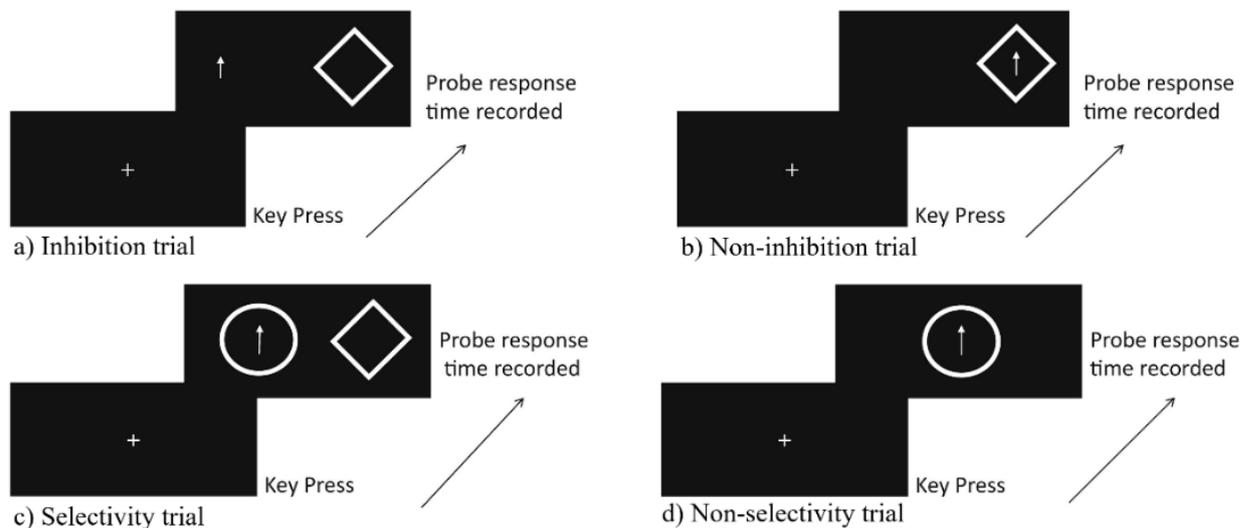


Figure 12. The Four Trials within the Attention Control Assessment Task.

The figure was taken from Basanovic et al. (2017).

In each trial, participants were instructed to fixate on the fixation cross and press the spacebar to start the trial. They then needed to respond to a target arrow presented on the screen that was pointing either up- or downward with the corresponding arrow keys on the keyboard. The target arrow was presented in different positions related to the shape according the block type. The order of the blocks was counterbalanced as described in Basanovic et al. (2017).

An index of control of attentional inhibition ( $AC_{\text{Inhibition}}$ ) was measured from RTs of inhibition and non-inhibition trials. In inhibition trials, participants needed to respond to a target presented in the location opposite to the shape. These trials, therefore, required participants to inhibit a pre-potent attentional movement towards the shape and execute an attentional movement to a location opposite to the salient shape stimulus (Basanovic et al., 2017). In non-inhibition trials, participants needed to respond to a target in the location of the shape (there was no need to inhibit the pre-potent attentional movement). Average RTs from non-inhibition trials were subtracted from the average RTs of inhibition trials. Smaller scores on the index of  $AC_{\text{Inhibition}}$  indicate a smaller cost to perform inhibition trials as compared to non-inhibition trials, and thus reflected greater control of attentional inhibition (Basanovic et al., 2017).

An index of control of attentional selectivity ( $AC_{\text{Selectivity}}$ ) was obtained from the mean RTs of selectivity and non-selectivity trials. In selectivity trials, participants needed to allocate their attention to a specified stimulus under conditions that

delivered competing stimuli. In non-selectivity trials, participants needed to allocate their attention to a specified stimulus under conditions that did not deliver competing stimuli. Average RTs from non-selectivity trials were subtracted from the average RTs from the selectivity trials, in which Smaller  $AC_{\text{Selectivity}}$  indicates a smaller cost to perform selectivity trials as compared to non-selectivity trials, and thus reflected greater control of attentional selectivity.

### **Data Preparation and Statistical Analyses**

Analyses, statistical outcomes, and errors were based on the same criteria as described in the methodology of Experiment 1, Chapter 2. The mean RTs for each trial type per Condition and Awareness category are reported in the Appendix Table 11. Out of these, the same bias index score (BIS) was calculated as described in Experiment 4 (mean RTs neutral trials – mean RTs angry trials). Two participants had an extreme attention bias score (a value more than 3 times the interquartile range) at baseline and another three participants had extreme scores in the second assessment phase and, therefore, were excluded from the following analysis. To test whether attention was biased at baseline towards angry compared to neutral faces, the mean BIS measured at baseline was compared to zero in a one-sample t-test. To further investigate whether attention bias changed in the training and assessment phases, the mean BIS were subjected to a 2 x 3 (Assessment [within training vs post-training] x Condition [angry-neutral vs neutral-angry vs control]) repeated measures mixed-design analyses of variance (ANOVA).

To examine whether elevated levels of anxiety were associated with an elevated pre-existing attention bias to angry faces at baseline, within training, and with attention bias change measured from pre- to post-training ( $AB_{\text{Change}}$ : mean BIS post-training assessment – mean BIS baseline assessment), correlations were computed between the sum scores of the STAI state, STAI trait, SIAS and SPS and the BIS measured at baseline, BIS measured within the training and with the  $AB_{\text{Change}}$  score.

In the attention control analyses, the same exclusion criteria were used as described in Basonovic (2017). Eleven participants were deleted from the final sample size as they made more than 10% of errors on the attention control task ( $M_{\text{PE}} = 31.2\%$ ,  $SD = 26.4$ , range: 10.2 – 100). The remaining 91 participants made 4.67% of errors in the ACA task ( $SD = 2.13$ , range: 1.56 – 9.38). To examine whether elevated levels of attentional control of inhibition and selectivity were associated

with attention bias acquisition and change, it was established whether there was an association between  $AC_{\text{Inhibition}}$  and  $AC_{\text{Selectivity}}$  and the BIS measured within training and the  $AB_{\text{Change}}$  score for each training condition separately. Correlations were computed between these variables (Bonferroni corrected,  $p < .017$ ).

To examine whether there was a significant difference between participant categorised as aware and not aware in attentional control scores of inhibition and selection, a 2 x 2 ANOVA with mean attention control ( $AC_{\text{Inhibition}}$  vs  $AC_{\text{Selectivity}}$ ) by Awareness (aware vs not aware) was tested. To test the hypothesis that awareness of the stimulus-probe contingency was a prerequisite of the trainability of participants' attention bias another BIS score was calculated. This BIS score was based on the congruency of the stimulus, not the emotional content. The congruency BIS (C-BIS) was calculated by subtracting the RTs of congruent trials of the RTs of incongruent trials. A positive score represents attention bias to the congruent stimulus, whereas a negative score represents an attention bias to the incongruent stimulus. To increase power of the analysis, it was necessary to use the C-BIS. As this score allows us to test whether there were differences in attention bias acquisition and change in those aware or not aware of the contingency, without including the two different training conditions in the analysis. A 2 x 2 (Assessment [within-training vs post-training] x Awareness [aware vs not aware]) ANOVA was conducted.

## Results

### Attention Bias at Baseline, Training and Assessment Phases

Figure 13 displays the mean BIS in each experimental phase for each training condition.

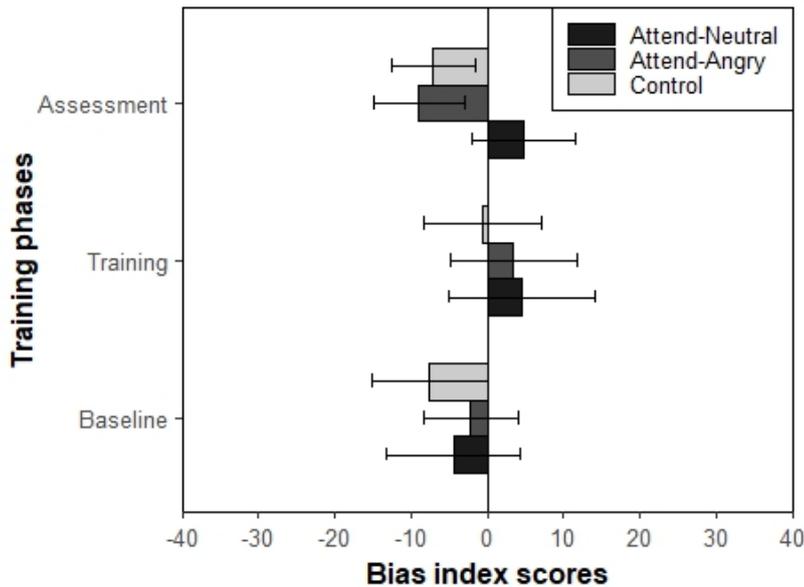


Figure 13. Emotional Bias Index Score at Baseline, within Training and Post-training Assessment Phase for Each Condition in Experiment 5.

Negative scores indicate an attention bias towards the neutral faces, whereas positive scores indicate an attention bias towards angry faces. Error bars represent standard error of the mean.

The one-sample t-test conducted with the mean BIS showed that in general participants did not prefer to attend to angry or neutral faces at baseline ( $M = -4.81$ ,  $SD = 42.3$ ),  $t(98) = -1.13$ ,  $p = .260$ ,  $95\%CI(-13.2, 3.62)$ . Furthermore, the ANOVA resulted in no significant effects, all  $F < 2.97$ ,  $p > .088$ ,  $\eta^2 < .031$ . These results indicate that the training phase of the dot-probe task was unable to induce an attention bias to the congruent stimuli in the two experimental conditions compared to the control. This suggest that the probe duration manipulation from 500ms to 700ms and simplification of the ABM paradigm did not facilitate attention bias acquisition and change.

### Anxiety and its Influence on Attention Bias Modification

On the SIAS, 44% of participants were above the clinical cut-off point in the 'attend-angry' condition, compared to 58% in the 'attend-neutral' condition, and 51% in the control condition. On the SPS, these percentages were 36%, 58%, and 31%, respectively. Only 8 of all participants had a STAI-state score above the clinical cut-off point ( $> 39$ ) and 13 out of all participants had a STAI-trait score above the clinical cut-off point. A one-way Analysis of Variance (ANOVA) indicated that there was no significant difference between conditions on the means of the anxiety scores shown in Table 7, all  $F < 1.01$ ,  $p > .369$ ,  $\eta^2 < .020$ .

Table 7.

*Descriptive Statistics of the Self-Reported Social, State, and Trait Anxiety Measures*

		Range	<i>M</i> ( <i>SD</i> )	Distribution <i>S</i> , <i>K</i>
Attend- angry ( <i>n</i> = 36)	SIAS	0 – 74	23.5(18.8)	1.01, .714
	SPS	0 – 74	17.0(17.8)	1.75, 2.99
	STAI state	20 – 70	32.0(14.1)	1.30, .618
	STAI trait	20 – 76	36.2(15.9)	1.08, .510
Attend- neutral ( <i>n</i> = 26)	SIAS	2 – 73	29.1(22.2)	.486, -1.06
	SPS	0 – 80	23.3(20.7)	.987, .744
	STAI state	20 – 72	34.5(13.9)	.993, 1.18
	STAI trait	20 – 76	38.5(15.9)	.812, -.140
Control ( <i>n</i> = 39)	SIAS	0 – 76	26.1(21.2)	.668, -.646
	SPS	0 – 80	17.7(17.9)	1.50, 2.49
	STAI state	20 – 72	34.5(13.0)	1.05, .079
	STAI trait	20 – 80	39.2(16.6)	.770, -.337

Note: *M*(*SD*) = Mean (standard deviation).

SIAS = social interaction anxiety scale. SPS = social phobia scale. STAI state = state sub-scale of the state/trait anxiety inventory. STAI trait = trait sub-scale of the state/trait anxiety inventory.

Cronbach's alpha of the measures were excellent (SIAS = .979, SPS = .969, STAI-S = .972, and STAI-T = .971).

Distribution is represented with Skewness (*S*) and Kurtosis (*K*), the standard errors of the distribution measures were between .378 and .887.

None of the self-reported anxiety measures correlated with the BIS measured at baseline, all  $r < -.127$ ,  $p > .212$ . This suggest that anxiety vulnerability was not associated with pre-existing attention bias. Figure 14 displays the overlay scatterplots of all anxiety measures and the BIS measured at baseline.

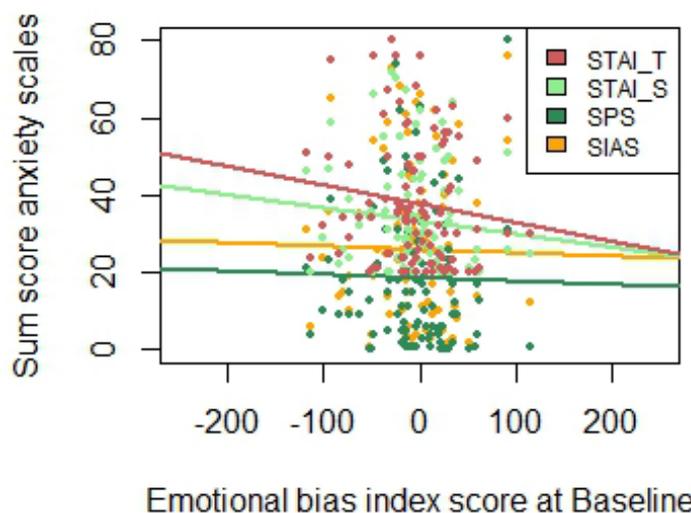


Figure 14. Association between State, Trait, and Social Anxiety and Emotional Bias Scores Measured at baseline. The solid lines represents the linear line of best fit.

None of the correlations between the STAI state, STAI trait, SIAS, and SPS scores and the BIS measured within-training assessment and the  $AB_{\text{Change}}$  score were significant in the active training conditions, all  $r < .256$ ,  $p > .151$  (see Figure 15).

This indicates that anxiety vulnerability was not associated with attention bias acquisition and change.

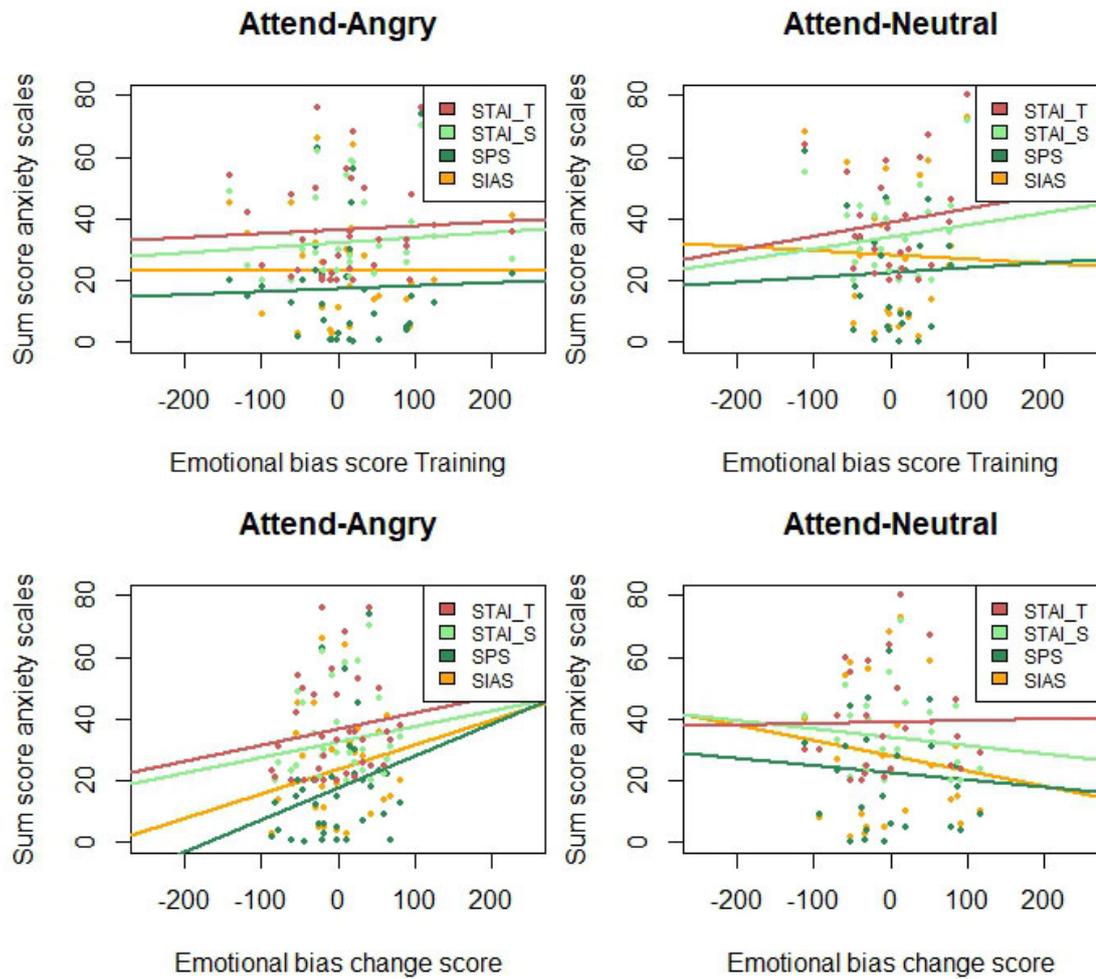


Figure 15. Association between State, Trait, and Social Anxiety and Emotional Bias Index Scores Measured within Each Training and as a Change Score from Pre- to Post-ABM for Each Active Training Condition in Experiment 5. The solid lines represents the linear line of best fit.

**Attention Control and its Influence on Attention Bias Modification**

The mean RT of each trial type is presented in Table 8. The overall mean  $AC_{Inhibition}$  was 39.3 ( $SD = 63.8$ ) and ranged from -84.9 to 297, the overall mean of  $AC_{Selectivity}$  was 258 ( $SD = 69.5$ ) and ranged between 88.4 and 454. Moreover,  $AC_{Inhibition}$  and  $AC_{Selectivity}$  did not correlate,  $r(84) = .133, p = .221$ , suggesting that these are two indices represent two independent constructs of attentional control.

Table 8.

*Mean Reaction Time Scores of Attention Control Trials in all Conditions*

Condition	Trial type	<i>M</i> ( <i>SD</i> )	Distribution ( <i>S</i> , <i>K</i> )
Attend-angry ( <i>n</i> = 34)	Inhibition	777(126)	.627, 1.25
	Non-Inhibition	730(88.5)	.482, .668
	Selectivity	828(114)	.463, 1.31
	Non-Selectivity	560(79.1)	.477, .571
Attend-neutral ( <i>n</i> = 24)	Inhibition	761(100)	.980, 1.20
	Non-Inhibition	733(103)	1.28, .472
	Selectivity	798(96.6)	1.33, 2.30
	Non-Selectivity	558(73.4)	1.24, 1.99
Control ( <i>n</i> = 34)	Inhibition	766(108)	.839, .667
	Non-Inhibition	727(95.1)	.722, -.541
	Selectivity	834(123)	.756, -.676
	Non-Selectivity	574(81.5)	.866, .740

*Note: M(SD) = Mean reaction time (standard deviation from the mean).*

*Distribution is represented with Skewness (S) and Kurtosis (K), the standard errors of the distribution measures were between .403 and .918.*

The ANOVA that tested attention control differences between conditions found a main effect for Attention Control Type,  $F(1, 84) = .593, p < .001, \eta^2 = .876$ , such that participants showed smaller cost of attentional inhibition ( $M = 33.8, SE = 6.08, 95\%CI[21.8, 45.8]$ ) and a higher cost of attentional selectivity ( $M = 256, SE = 7.68, 95\%CI[241, 272]$ ). There was no interaction between Attentional Control Type and Condition,  $F(2, 84) = .575, p = .565, \eta^2 = .014$ . This indicates that there were no differences in attention control between training conditions. Furthermore, as shown in Figure 16, the pre-existing attention bias measured at baseline did not correlate with attentional control measures, both  $r < .109, p > .312$ . The hypothesis that stated that higher levels of attentional control are related to lower pre-existing attention bias was rejected.

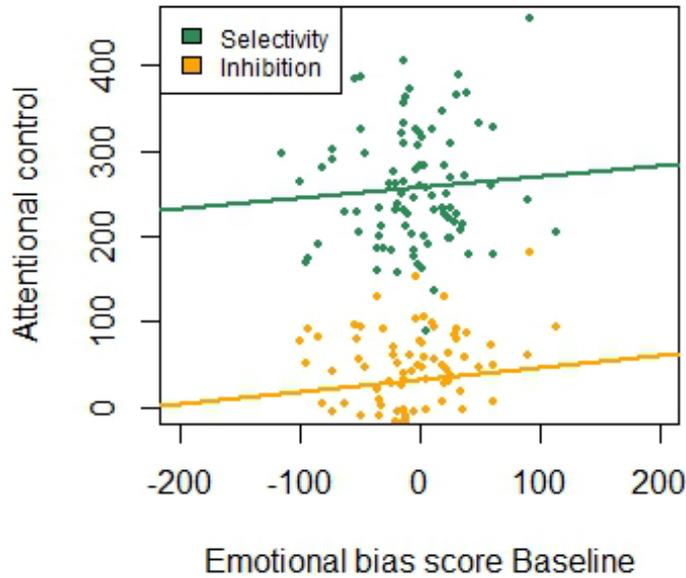


Figure 16. Association between Attentional Control of Inhibition and Selectivity and the Pre-Existing Attention Bias measured at Baseline in Experiment 5. The solid lines represents the linear line of best fit.

There were no significant correlations between  $AC_{\text{Selectivity}}$  and the BIS within training or the  $AB_{\text{Change}}$  score in neither training condition, all  $r < -.216, p > .321$ . None of the correlations between  $AC_{\text{Inhibition}}$  and the BIS or  $AB_{\text{Change}}$  scores were significant for the ‘attend-angry’ condition, all  $r < .219, p > .253$ . In the ‘attend-neutral’ condition, there was a significant positive correlation between  $AC_{\text{Inhibition}}$  and the BIS measure within training,  $r(21) = .634, p = .001$ , however, not with the  $AB_{\text{Change}}$  score,  $r(21) = -.184, p = .402$ . Figure 17 displays the overlay scatterplots of both attention control measures and the BIS measured within training (top row) and  $AB_{\text{Change}}$  scores (bottom row) for each active training condition.

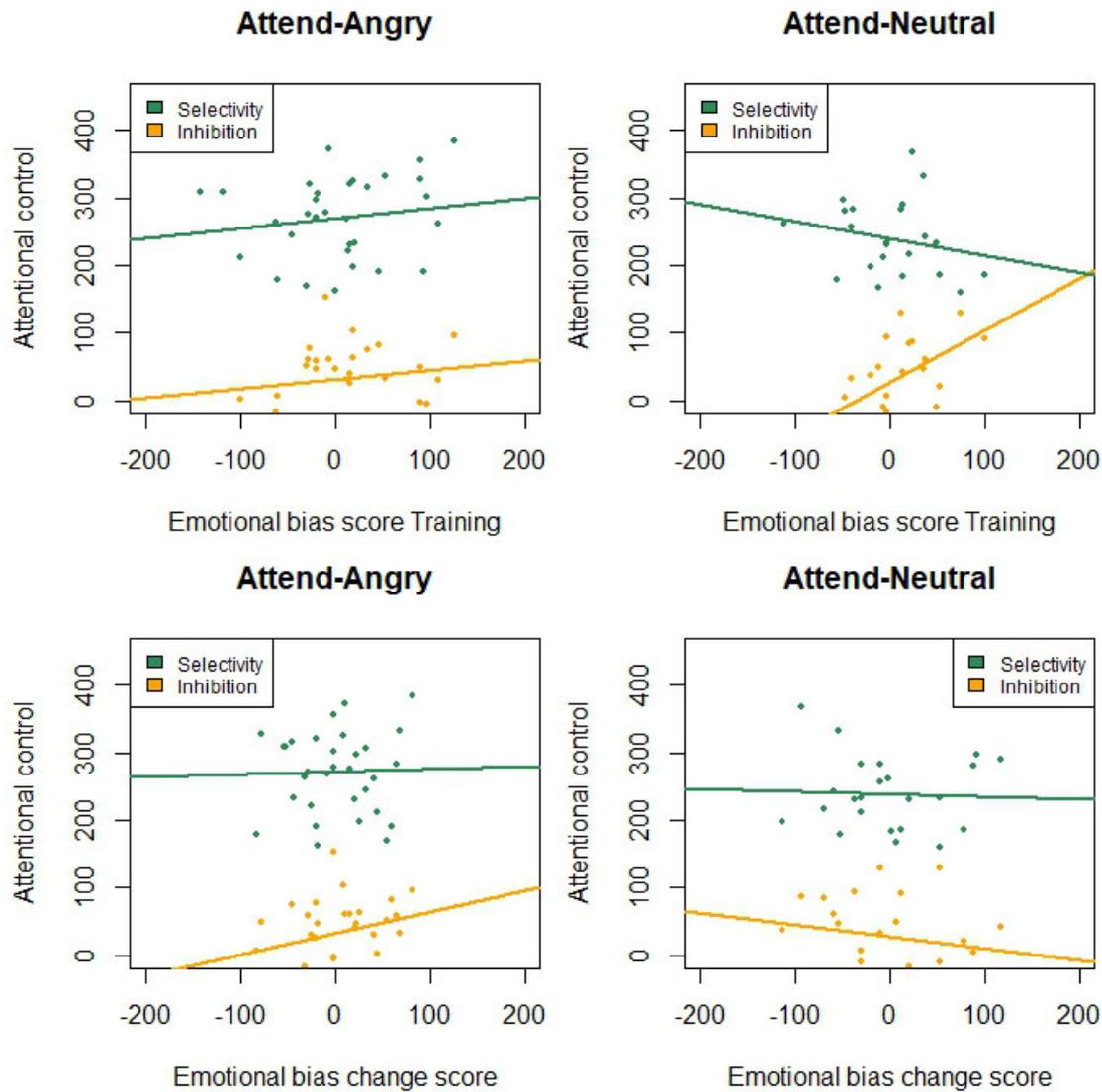


Figure 17. Association between Attention Control and Congruency Bias Index Score Measured within Training (top row) and as a Bias Change Score (bottom row) for Each Active Training Condition in Experiment 5. The solid lines represents the linear line of best fit.

The association between levels of attention control of inhibition and trainability toward neutral faces when measured within the training was in line with predictions. Specifically, those with lower attentional cost of inhibition (better attention control) responded quicker to the probes in congruent (neutral face) rather than to probes in the incongruent (angry face) trials during training. This suggest that better attention control was associated with attention bias acquisition in the targeted direction during the within-training assessment.

In addition, the ANOVA with mean attention control by contingency awareness resulted in a main effect of attentional control,  $F(1, 51) = 496, p < .001, \eta^2 = .907$  and a trending interaction effect,  $F(1, 51) = 3.13, p = .083, \eta^2 = .058$ . It seems

that those aware of the stimulus-probe contingency have a marginal higher cost of attentional selectivity ( $M = 275$ ,  $SE = 12.7$ ,  $95\%CI[250, 301]$ ) than those not aware of the contingency during ABM ( $M = 244$ ,  $SE = 10.3$ ,  $95\%CI[224, 265]$ ),  $t(51) = 1.89$ ,  $p = .064$ ,  $95\%CI(-1.91, 63.7)$ . This difference was not evident in the attentional cost of inhibition (aware:  $M = 28.2$ ,  $SE = 11.6$ ,  $95\%CI[4.95, 51.5]$  and not aware:  $M = 23.6$ ,  $SE = 9.39$ ,  $95\%CI[14.8, 52.5]$ ),  $t(51) = .364$ ,  $p = .717$ ,  $95\%CI(-35.4, 24.5)$ . This suggest that attentional control does not facilitate contingency awareness as hypothesised. In contrast to what was expected, the results indicated that lower attentional control of selectivity was evident in those aware of the contingency compared to those not aware.

### **Awareness of Stimulus-Probe Contingency and its Influence on Attention Bias Modification**

Approximately 40% of participants acquired awareness of the stimulus-probe contingency; this was significantly more compared to the previous experiment,  $X^2(1) = 9.67$ ,  $p = .002$ ,  $\phi = .289$ . Interestingly, the number of participants who became aware in the ‘attend-neutral’ training condition ( $n = 5$ ; 23%) was significantly lower compared to those in the ‘attend-angry’ training condition ( $n = 17$ ; 77%),  $X^2(1) = 5.55$ ,  $p = .019$ ,  $\phi = .307$ . Additionally, there were significant differences in state and trait anxiety between those aware and not aware of the contingency, all  $F > 5.10$ ,  $p < .028$ ,  $\eta^2 > .082$ , however, no differences in the social anxiety measures,  $F < 2.52$ ,  $p > .118$ ,  $\eta^2 < .042$ . Participants aware of the contingency displayed lower levels of state ( $M = 27.7$ ,  $SD = 10.4$ ) and trait anxiety ( $M = 31.6$ ,  $SD = 11.1$ ) than those unaware of the contingency (state:  $M = 36.6$ ,  $SD = 14.5$  and trait:  $M = 41.3$ ,  $SD = 18.0$ ).

The ANOVA resulted in a trending main effect of assessment point,  $F(1.57) = 2.98$ ,  $p = .090$ ,  $\eta^2 = .050$ , such that there was a larger C-BIS found in the training phase ( $M = -10.1$ ,  $SE = 8.53$ ,  $95\%CI[-27.2, 6.93]$ ) than in the assessment phase post-training ( $M = 3.70$ ,  $SE = 4.36$ ,  $95\%CI[-5.03, 12.4]$ ). The interaction effect did not reach significance,  $F(1.57) = .017$ ,  $p = .896$ ,  $\eta^2 < .001$ . This suggest that there were no differences in congruency bias in training and post-training assessment phases between those in the experimental group that became aware ( $n = 22$ ) or not aware ( $n = 37$ ) of the training (see Figure 18).

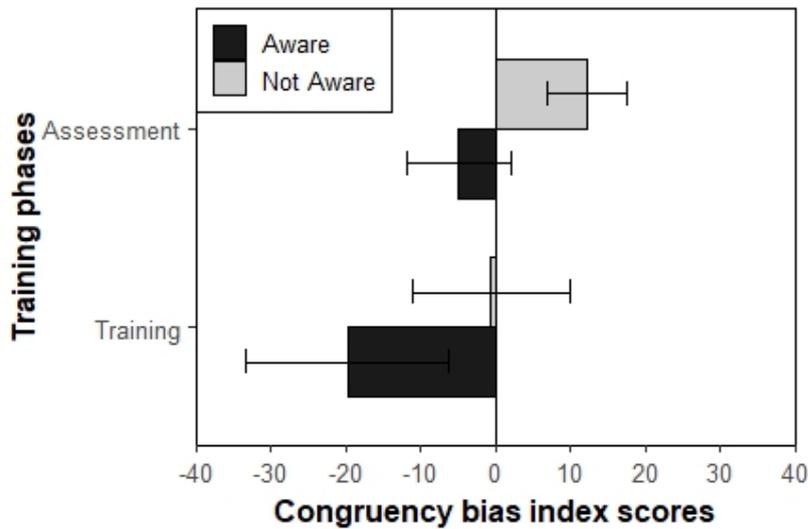


Figure 18. Congruency Bias Index Scores for those Aware and Not Aware of the Stimulus-Probe Contingency in Experiment 5.

Negative scores indicate an attention bias to congruent stimuli, whereas positive scores indicate an attention bias to incongruent stimuli. Error bars represent standard error of the mean.

### Strategies Used to Perform the Dot-Probe Task

Qualitative responses were categorised into four themes and are reported in Table 9, these were: (1) No strategy used (e.g., “No”); (2) Focused on the probes (e.g., “I had to ignore the faces to be able to focus on the tiny dots. When I started looking at faces I messed up.”); (3) Focused on certain location of the screen (e.g., “If I didn't see the dots on one side I quickly shifted to the other side.”); (4) Faces predicted the probe (e.g., “I tried looking for an angry face once I noticed they were coming that side, but that wasn't entirely predictable. So I think I might have slowed down”).

Table 9.

#### Strategies Used to Perform the Dot-Probe Task in Each Training Condition

Themes	Attend-angry	Attend-neutral	Control
No strategy used	$n = 19$ (53%)	$n = 15$ (58%)	$n = 24$ (62%)
Focused on the probes	$n = 12$ (33%)	$n = 6$ (23%)	$n = 8$ (21%)
Focused on certain location of the screen	$n = 3$ (8%)	$n = 2$ (8%)	$n = 5$ (13%)
Shape predicted the probe	$n = 1$ (2%)	$n = 1$ (4%)	$n = 1$ (3%)

Note: One missing value in the ‘attend-angry’ condition, two missing values in the ‘attend-neutral’ condition and one missing value in the control condition.

The type of strategy used did not differ per training condition,  $X^2(6) = 2.12$ ,  $p = .908$ ,  $\phi = .148$  and are not further analysed because of the small numbers.

### Discussion

Compared to Experiment 4, in Experiment 5 we changed the task parameters (probe duration from 500ms to 700ms) and study design (the reversed training and post-training assessment phases were omitted) to decrease the difficulty level of the dot-probe task and ABM procedure. In turn, it was hypothesised that, with emotional stimuli, these manipulations would facilitate contingency learning and the acquisition of contingency awareness. It was hypothesised that attention bias could successfully be acquired and changed using the stimulus-probe associations in the dot-probe task. However, consistent with Experiment 4, no attention bias was acquired or changed to angry faces in individuals trained to attend to angry faces and no attention bias was acquired or changed to neutral faces in those trained to attend to neutral faces. Furthermore, participants did not have a pre-existing attention bias to angry faces at baseline. It is possible that the manipulations did not help most participants to pay attention to the stimulus and as a result they did not learn the stimulus-probe associations.

There were no associations between levels of anxiety vulnerability (state, trait, and social anxiety) and pre-existing attention bias or with the magnitude of attention bias acquisition (within-training) and change (from pre- to post-training). This finding was evident despite the high variety of anxiety vulnerability in the sample. This is troubling as the appropriateness of ABM training has been questioned for anxious individuals who lack a negative attention bias or who may already be threat-avoidant (Eldar et al., 2012; Van Bockstaele et al., 2014). Given that some studies have found an association between emotional vulnerability and attention bias (see for overview: Bar-Haim et al. (2007)), whereas others have not (e.g., Amir, Beard, Burns, & Bomyea, 2009; Badura-Brack et al., 2015; Boettcher, Hasselrot, Sund, Andersson, & Carlbring, 2013; J. Boettcher et al., 2013; Britton et al., 2015; Enock, Hofmann, & McNally, 2014; Kuckertz et al., 2014; McNally, Enock, Tsai, & Tousian, 2013; Yao, Yu, Qian, & Li, 2015), it is likely that other unknown factors moderate the relationship between emotion vulnerability and attention bias.

One such factor may lay in the design of the dot-probe task (i.e., specific task parameters). It is possible that the dot-probe task with emotional stimuli needs to be tailored to facilitate learning of the stimulus-probe association. The results of Experiment 4 and 5 suggest that the decrease in probe duration may not have been sufficient to facilitate stimulus-probe contingency learning with the dot-probe task. It

is possible that a probe duration limitation in the dot-probe task with emotional stimuli hinders contingency learning. Furthermore, it may be that the probe size needs to be increased as most participants reported that they focussed on the small probes to perform the dot-probe task and ignored the faces as these distracted them from locating the small probes. Overall, these results revealed that a stimulus-probe association in the dot-probe task is not easily established. Future research is required to investigate which parameters (i.e., probe size and probe duration) in the dot-probe task are conducive to stimulus-probe associative learning and results in attention bias change.

The probe duration manipulation and the simplification of the ABM design resulted in higher numbers of participants who acquired awareness of the stimulus-probe contingency. Over 40% of participants became aware of the stimulus-probe contingency as opposed to less than 10% in Experiment 4. The manipulations in the procedure may have aided contingency awareness; however, it did not aid contingency learning as evidenced by the lack of attention bias acquisition and change in the ABM procedure. Thus, the hypothesis, which stated that stimulus-probe associative learning would be facilitated by the employment of a simpler dot-probe task in a simpler ABM paradigm through contingency awareness, was rejected. Contingency awareness did not facilitate attention bias acquisition and change from pre- to post-training. Participants, who reported themselves to be aware or not aware of the contingency, exhibited no different attention bias patterns across the ABM paradigm. Though, there was evidence to suggest that contingency awareness was associated with the training condition. More participants were aware of the contingency when they were in the 'attend-angry' (53%) compared to the 'attend-neutral' training condition (19%). However, the results showed that this effect was not driven by the emotional content of the stimuli that predicted the probe in either active training condition. That is, in contrast to the predictions of the attention and emotion theories (described in Chapter 1) and the associative learning theories (Mackintosh, 1975; Rescorla & Wagner, 1972), emotion did not capture attention, as evidenced by non-existent attention bias at baseline. Overall, the results suggest that the change in task parameters in the dot-probe task, however, not the emotional content of stimuli, facilitated contingency awareness for some participants. Moreover, it is likely that there are other individual differences, which require further

investigation. Other factors may explain why some individuals acquired awareness of the contingency, while others did not.

The acquisition of contingency awareness seems to be dependent on individual differences in anxiety vulnerability and attention control. There were significant differences in state and trait anxiety between those aware and not aware of the contingency. Individuals low in state and trait anxiety were more likely to become aware of the stimulus-probe contingency. However, this difference did not result in differences in pre-existing attention bias at baseline or in attention bias acquisition and change. Furthermore, the acquisition of contingency awareness was related to attentional control of selectivity, however, not to attentional control of inhibition. The results showed that those aware of the stimulus-probe contingency had a marginally higher cost of attentional control of selectivity than those who reported not to be aware of the contingency during ABM. This suggests, contrary to the hypothesis, that lower attentional control is associated with acquiring contingency awareness. However, given that this effect was only marginally significant, it has to be interpreted with caution. More research is needed to determine predictors of the acquisition of stimulus-probe contingency awareness in those who complete the dot-probe task.

It was found that individual differences in attentional control were associated with individual differences in attention bias trainability. However, this effect was limited to attentional control of inhibition (not selectivity) and the association was only found with attention bias measured within the training phase (not with bias change measured from pre-to post-training assessments). Importantly, the association was only evident in individuals that completed the ‘attend-neutral’ training condition. Since attention control was measured after the attention training it is possible that high levels of inhibitory control were developed in participants who inhibited the emotional distractor stimuli in order to attend to the neutral face that predicted the probe in training. The lack of the association in the ‘attend-angry’ condition may reflect that participants did not develop inhibitory control as they were not required to inhibit their attention from emotion. This finding is partially consistent with the prediction that higher attentional control is associated with attention bias acquisition and change, as this association was limited to attentional control of inhibition, limited to the attention bias measured in the training phase and only found in participants who completed the ‘attend-neutral’ training.

The result of the current study, which indicated that higher inhibitory attentional control was related to attention bias acquisition are partially in line with Basanovic et al. (2017) and Everaert et al. (2017). Basanovic et al. (2017) found a greater effect for attentional control of inhibition and a marginal effect for attentional control of selectivity, while Everaert et al. (2017) only measured attentional control of inhibition and found the same association with attention bias change. These findings indicated that there seems to be more evidence for the influence of attentional control of inhibition than selection on attention bias malleability. However, in contrast to the current findings, Basanovic et al. (2017) and Everaert et al. (2017) found that attentional control was associated with attention bias change measure from pre- to post-training (they had no measure within training). Furthermore, the current findings showed that attention training where emotional stimuli needs to be ignored increases attentional inhibitory control. This adds to the previous finding of Basanovic et al. (2017) and Everaert et al. (2017), which states that attention bias malleability was associated with attentional control of inhibition.

The idea that ABM increases attentional control was tested in Chen, Clarke, Watson, MacLeod, and Guastella (2015). Chen et al. (2015) found that attention control of inhibition increased after ABM compared to placebo training. Moreover, the increase in attentional control assessed in Chen et al. (2015) did not mediate the direct relationship between ABM and attention bias change. This suggest that ABM possibly changes attention control, however, it may not be the sole mechanism that drives attention bias change. Given that the methodologies of the current experiment and the experiment conducted by Chen et al. (2015) are inadequate in assessing the mechanism, related to attention control, that drives attention bias change, further research is needed to establish the role of attentional control of inhibition and attention bias acquisition and change.

### **General Discussion of Experiments 4 and 5**

In this chapter, two experiments were described which used the dot-probe task with emotional stimuli to investigate the influence of individual differences in contingency awareness, anxiety vulnerability and attention control on the stimulus-probe associative learning mechanism that underlies attention bias acquisition and change. Based on the findings of the first three experiments described in Chapter 2, it was hypothesised that contingency awareness is a prerequisite of attention bias acquisition and change. Furthermore, based on previous literature and attention and

emotion theories described in Chapter 1, it was hypothesised that higher levels of anxiety vulnerability and attention control were associated with magnitude of attention bias at baseline, attention bias acquisition in training and attention bias change from pre- to post-training. The main findings in the two experiments, described in this chapter, indicated that attention was not biased at baseline or induced with a stimulus-probe association in training. Furthermore, only the individual difference in attention control of inhibition was associated with attention bias acquisition.

The dot-probe task assesses a pre-existing negative attention bias by providing two stimuli with negative and neutral valence simultaneously on the screen. It is generally assumed that participants who have a negative attention bias attend more to the negative than the neutral stimuli. This aids them in locating the probe, which was in the congruent location with the negatively attended stimulus, however, hinders them in locating the probe in the negatively incongruent location with attended stimulus (i.e., when the probe is located in the same location as the neutral stimulus). This result in RT patterns is indicative of a negative attention bias (i.e., relative quicker responding to probes that were preceded by the negative, compared to the neutral stimuli). In addition, it is assumed that in training, participants learn to use the congruent stimuli to predict the location of the probe, which in turn changes attention bias patterns. However, across both experiments, selective attention was not biased at baseline, neither was attention bias acquired or changed as a result of the contingencies employed in the dot-probe training task. Furthermore, across both experiments, levels of state, trait and social anxiety were not associated with attention bias at baseline. This is in contrast to the attention and emotion theories (described in Chapter 1) and to numerous studies that found an attention bias toward emotional stimuli in emotionally vulnerable individuals (i.e., high in anxiety) when compared to non-vulnerable individuals (i.e., low in anxiety; Aspen et al., 2013; Bar-Haim et al., 2007; Dudeney et al., 2015; Hallion & Ruscio, 2011; Harris et al., 2015; Hughes, Hirsch, Chalder, & Moss-Morris, 2016; Rodgers & DuBois, 2016; Schoth et al., 2012). However, given that participants in our samples were not preselected on high or low anxiety, it is likely that the task was not optimally designed to capture significant attention bias differences in our sample (Bantin et al., 2016).

One obvious explanation of why the dot-probe task did not detect any pre-existing bias nor induced an attention bias change in the sample, may be related to the possibility that not all participants attended to the stimuli in the dot-probe task as assumed. Therefore, participant's RTs were not influenced by biased attention at baseline or during training. However, as this may be true for the participants who were excluded for poor accuracy, the picture is probably more complex than that. In Experiment 5, attention bias acquisition was associated with attention control, which clearly indicates that attention was being paid to the contingency by some participants or at least at some level. Emotional expressions in faces are processed very rapidly, as evidenced by the situation in the classic emotion-induced blindness paradigm (e.g., de Jong, Koster, van Wees, & Martens, 2009). In such paradigms, participants are unable to avoid processing of emotional distractors that appear in the same location as an upcoming target. However, in contrast to the dot-probe paradigm, in the induced blindness paradigm, participants do not need to associate the location of the facial stimuli with the location of the probe to facilitate responding. Therefore, participants may have processed the facial stimuli, however, they may not have processed the contingency (i.e., that the location of the probe was predicted by a certain facial expression).

The findings of Experiment 5 suggest that those with higher inhibitory attentional control may process the facial stimuli and the stimulus-probe contingency. The results showed that participants who received stimulus-probe association training to drive selective attention to neutral stimuli, and thus had to ignore the emotional stimuli, showed greater inhibitory attentional control in a subsequent attention control task. However, the findings showed that attentional control of inhibition was not associated with contingency awareness, only those aware of the contingency during ABM had a marginal higher cost of attentional control of selectivity. Therefore, it is likely that some participants ignored the stimuli and only focus on the probes to perform the task, whereas, others do not. The factors predicting why only some participants attend to the stimuli remain unknown. Overall, the dot-probe task, in its current form, is unable to ascertain whether participants pay attention to the stimuli to predict the probe.

It seems that manipulations in task parameters influence contingency awareness. However, the influence of contingency awareness on attention bias acquisition found in the experiments that used non-emotional stimuli (described in

Chapter 2) and found in previous studies (Grafton et al., 2014; Lazarov et al., 2017) was not replicated in the current experiments that used emotional stimuli. It is possible that the task parameters need to be further adjusted, so that more participants become aware of the contingency. This in turn will increase the power of the analysis that assesses whether different attention bias patterns are evident in those aware, versus not aware, of the stimulus-probe contingency.

### **Conclusion Experiments 4 and 5**

The probe duration manipulation in the dot-probe task and the simplification of the ABM paradigm did not result in attention bias patterns at baseline, nor within- or post-training. It was discussed that not all participants attended the stimuli to predict the location of the probe. Furthermore, individual differences in anxiety vulnerability, contingency awareness and attention control of selectivity were assessed, however, these could not explain the lack of attention bias assessment, acquisition or change. Attentional control of inhibition was the only variable associated with attention bias acquisition in training. Moreover, only those who were trained to attend to neutral faces, while ignoring angry faces, showed an association with inhibitory attentional control assessed in a subsequent attention control task. This association was not evident in participants who were trained to attend to angry faces. This suggest that some participants, most likely those with high attention control of inhibition, paid attention to the stimuli, while others ignored them. The hypotheses considered attentional control as an individual trait that was expected to explain variance in attention bias acquisition. However, attention control of inhibition was related to the valence of the training (i.e., 'attend-neutral' condition), and therefore, may be a personal trait that can be strengthened by the neutral stimulus-probe associative learning mechanism. Overall, further research needs to be conducted to determine what adjustments need to be made in the task parameters of the dot-probe task to achieve stimulus-probe contingency learning that can reliably assess attention bias at baseline as well as induce or change an attention bias in training. Furthermore, future research needs to be conducted to establish how individual differences, such as contingency awareness, attentional control, attention to stimulus, and emotion vulnerability interact in the establishment of the stimulus-probe association in the dot-probe task, which in turn results in a reliable attention bias assessment, acquisition and change. An integrated view of these factors could

possibly enhance understanding of the mixed results found in regard to attention bias to threat assessment and ABM training.

## Appendix Chapter 3

Table 10.

*Mean Reaction Time, Standard Deviation and Distribution for Angry- and Neutral-Target Trials per Training Condition Experiment 4*

Condition	Phase	Trial type	<i>M(SD)</i>	Distribution ( <i>S, K</i> )
Angry-Neutral ( <i>n</i> = 32)	Baseline ( <i>n</i> = 31)	Angry-trial	696(145)	.273, -.226
		Neutral-trial	685(167)	.919, 1.26
	Training 1	Angry-trial	678(142)	-.148, -1.14
		Neutral-trial	668(136)	.200, -.597
	Assessment 1	Angry-trial	641(129)	.237, .753
		Neutral-trial	638(123)	.128, -.267
	Training 2	Angry-trial	626(110)	-.175, -.575
		Neutral-trial	633(121)	-.165, -.049
	Assessment 2	Angry-trial	631(151)	1.40, 3.61
		Neutral-trial	628(146)	1.12, 2.03
Neutral-Angry ( <i>n</i> = 26)	Baseline	Angry-trial	740(153)	.605, 1.90
		Neutral-trial	725(145)	.516, 1.29
	Training 1	Angry-trial	675(142)	.160, -.909
		Neutral-trial	675(147)	.037, -.753
	Assessment 1	Angry-trial	655(131)	-.034, -.684
		Neutral-trial	653(126)	.266, -.271
	Training 2	Angry-trial	624(118)	-.110, -.953
		Neutral-trial	635(124)	.379, -.369
	Assessment 2	Angry-trial	622(125)	.531, .663
		Neutral-trial	610(122)	.893, 1.66
Control ( <i>n</i> = 33)	Baseline	Angry-trial	740(153)	.605, 1.90
		Neutral-trial	725(145)	.516, 1.29
	Training 1	Angry-trial	675(142)	.160, -.909
		Neutral-trial	675(147)	.037, -.753
	Assessment 1	Angry-trial	655(131)	-.034, -.684
		Neutral-trial	653(126)	.266, -.271
	Training 2	Angry-trial	624(118)	-.110, -.953
		Neutral-trial	635(124)	.379, -.369
	Assessment 2	Angry-trial	622(125)	.531, .663
		Neutral-trial	610(122)	.893, 1.66

*Note: M(SD) = Mean reaction time (standard deviation from the mean).*

*The normality of the distribution was assessed with the Skewness (S) and Kurtosis (K) measures. Standard errors of Skewness were below .409, standard errors of Kurtosis were below .798.*

Table 11.  
*Mean Reaction Time, Standard Deviation and Distribution for Angry- and Neutral-Target Trials per Training Condition Experiment 5*

Condition	Phase	Trial type	<i>M(SD)</i>	Distribution ( <i>S, K</i> )
Attend- angry, aware of the contingency ( <i>n</i> = 19)	Baseline	Angry-trial	671(150)	2.20, 6.97
	Assessment	Neutral-trial	675(145)	1.71, 4.02
	Training	Angry-trial	638(98)	1.33, 2.08
		Neutral-trial	669(156)	1.04, .712
	Post- Assessment	Angry-trial	638(112)	.887, .199
		Neutral-trial	638(121)	1.04, .519
Attend- angry, not aware of the contingency ( <i>n</i> = 17)	Baseline	Angry-trial	629(130)	.923, .379
	Assessment	Neutral-trial	620(140)	1.03, .376
	Training	Angry-trial	614(97.8)	.255, -.237
		Neutral-trial	608(71.7)	-1.04, .293
	Post- Assessment	Angry-trial	601(70.6)	-.471, .187
		Neutral-trial	584(69.6)	-.351, .610
Attend- neutral, aware of the contingency ( <i>n</i> = 5)	Baseline	Angry-trial	717(187)	.223, -2.94
	Assessment	Neutral-trial	706(186)	.482, -2.37
	Training	Angry-trial	648(84.7)	.864, 1.70
		Neutral-trial	646(103)	.496, -.677
	Post- Assessment	Angry-trial	608(102)	1.27, 2.35
		Neutral-trial	619(128)	1.06, .912
Attend- neutral, not aware of the contingency ( <i>n</i> = 21)	Baseline	Angry-trial	615(164)	.890, -.152
	Assessment	Neutral-trial	605(138)	.679, -.767
	Training	Angry-trial	575(107)	.869, .160
		Neutral-trial	584(124)	.675, -.557
	Post- Assessment	Angry-trial	557(93.1)	.183, -.459
		Neutral-trial	559(130)	1.55, 3.58
Control ( <i>n</i> = 26)	Baseline	Angry-trial	635(169)	.710, -.718
	Assessment	Neutral-trial	624(150)	.694, -.708
	Training	Angry-trial	589(105)	.620, -.276
		Neutral-trial	596(121)	.502, -.762
	Post- Assessment	Angry-trial	567(94.9)	.314, -.118
		Neutral-trial	571(129)	1.31, 2.30

*Note: M(SD) = Mean reaction time (standard deviation from the mean).*

*The normality of the distribution was assessed with the Skewness (S) and Kurtosis (K) measures. Standard errors of Skewness were below .550, standard errors of Kurtosis were below 1.06.*

## Chapter 4

### Study 2

The previous chapters gave an overview of the difficulties encountered when assessing, inducing, and changing attention bias in an attention bias modification (ABM) paradigm utilising the conventional dot-probe task. It was concluded that contingency learning in the dot-probe task was not always achieved and it may be dependent on factors like contingency awareness and attentional control. This uncertainty and dependence is problematic since contingency learning is necessary for successful, stable, and long-term attention bias change in order to subsequently reduce emotion vulnerability (MacLeod & Clarke, 2015). Thus, attention bias may not be acquired or changed via a bottom-up stimulus-probe associative approach. Other, higher-order processes, like contingency awareness and attention control seem to influence whether the dot-probe task can achieve its outcome. In addition, from widespread anecdotal reports, participant boredom has always been a concern regarding the dot-probe training task. Boredom is especially problematic because it has been shown that multiple training sessions can be efficacious in reducing anxiety symptoms (Amir et al., 2009; Schmidt et al., 2009) as well as that more frequent brief learning sessions are more suited to skills training than infrequent, longer sessions (Bjork, 2017). Given that the dot-probe task has been characterised as boring, repeated training sessions, as it is now, may not be suitable as a training tool for clinical adaptation. Participants may feel reluctant to complete the multiple sessions necessary to achieve attention bias change.

### **Gamification of Attention Bias Modification**

Recently, aside from modifying attention bias with the conventional dot-probe task, other variations of ABM tasks have been developed to modify attention bias. Researchers have attempted to create more engaging ABM tasks by employing principles of ‘gamification’. ABM tasks can be gamified by including motivational feedback (e.g., sounds, graphics that indicate completion rate), rewards for performance (points, badges, levels, special powers or privileges), and a cohesive story (with consistent actions, sounds, graphics, etc.; Boendermaker, Prins, & Wiers, 2013). Essentially, these alterations increase participants’ motivation to engage with the task. It is acknowledged that motivation plays an important role in cognitive control, which in turn can increase performance on attentional tasks (Botvinick & Braver, 2015). Heightened motivation does not only facilitate memory and

perceptual attention, it also positively affects attentional control, such as action selection and inhibition, and other control functions that encode and maintain a representation of the current task (i.e., action-outcome contingencies, relevant stimulus-response associations, and target states or goals; Botvinick & Braver, 2015). The specific role of motivation in gamified ABM tasks, and whether it may be the driving factor in increasing effectiveness of attention bias change compared to a conventional dot-probe ABM task, has not yet been studied. Forman et al. (2018) pointed out some limitations of gamifying ABM. These were that the creation of gamified trainings requires skills and resources, as well as that it implicates the risks of undermining the integrity of the attention training, thus resulting in reduced efficacy. However, benefits of gamification over the conventional dot-probe task involve an increase of adherence to repeated trainings, which should increase efficacy.

Studies that have tested the efficacy of gamified ABM tasks to alter attention bias and anxiety have shown promising results. Examples of gamified ABM training tasks are the person-identity-matching (PIM) task (Notebaert, Clarke, Grafton, & MacLeod, 2015), the intrinsically-motivating playable attentional control training (IMPACT; Enock, 2015), personal zen (Dennis & O'Toole, 2014), and the emotion-in-motion task (Notebaert et al., 2018). All tasks included game features like a point system (Enock, 2015; Notebaert et al., 2015; Notebaert et al., 2018), colour changes reflecting success or failure (Enock, 2015; Notebaert et al., 2015), sound effects (Enock, 2015), or a story line (Dennis & O'Toole, 2014). In each gamified ABM training, participants were encouraged to try to improve their high score. Higher scores were obtained when participants successfully attended to a certain stimulus valence.

The method by which participants were trained to a certain stimulus valence, and thus achieved a high score, was different across tasks. In the PIM task participants were presented with virtual cards depicting face pairs with happy and angry expressions. Selective attention towards or away from threat was modified by requiring participants to either match only angry faces (and ignore the happy faces) or only match the happy faces (and ignore the angry faces) across sequential card pairs (Notebaert et al., 2015). In the IMPACT task, faces, reflecting happiness and disgust expressions, continuously descended from the top to the bottom of the screen and participants were either trained to attend towards or away from threat by clicking

on the target face twice to prevent them from hitting the bottom of the screen (Enock, 2015; and replicated by Pieters et al., 2017). In the personal zen game, participants were shown two animated faces, one angry and one neutral, and were instructed to make a swipe motion that followed either the angry or neutral character. In the emotion-in-motion task, a target would move around the screen amid seven moving distractors. The target was either a happy facial expression amid angry facial expressions, or an angry facial expression amid happy facial expressions, resulting in two training conditions ('attend-happy' and 'attend-angry'). Participants were instructed to follow the target with their mouse, however, the target would randomly disappear from one and appear in another frame position. Hence, participants needed to relocate the target and continue tracking it with their mouse (Notebaert et al., 2018).

Most gamified attention bias training resulted in attention bias change (Dennis & O'Toole, 2014; Enock, 2015; Notebaert et al., 2015; Pieters et al., 2017), this change was, however, only evident in the 'attend-happy' condition in the emotion-in-motion task (Notebaert et al., 2018). Furthermore, not all tasks were successful in significantly reducing emotional reactivity in the positive compared to the negative valenced training conditions as measured with a stressor post-training (Enock, 2015; Notebaert et al., 2015; Notebaert et al., 2018; Pieters et al., 2017). The PIM (Notebaert et al., 2015) and emotion-in-motion task (Notebaert et al., 2018) both found an attenuated effect in emotional reactivity in the 'attend-happy' compared to the 'attend-angry' training condition. Lastly, personal zen achieved a significant reduction in anxiety levels post-training (Dennis & O'Toole, 2014), however, this effect was only replicated in females (Dennis-Tiwary, Egan, Babkirk, & Denefrio, 2016).

It appears that gamified ABM can be a promising step forward in changing attention bias patterns from the conventional dot-probe task. To further investigate the differences in attention bias change between the conventional dot-probe task and gamified ABM, the current study compared the dot-probe task with the latest gamified ABM task, the emotion-in-motion task. Previous studies that compared gamified ABM training tasks to the conventional dot-probe task have focussed on the effect on emotion vulnerability. However, less is known about how attention bias patterns change when the dot-probe task or gamified ABM tasks are used. Therefore,

the specific focus in the current study was to examine the possible differences in the processes that underlie attention bias change.

### **Modification of the Attentional Engagement and Disengagement Processes**

The main aim of this experiment was to investigate the processes that have the potential to underlie attention bias change as a result of the dot-probe and emotion-in-motion task. Two processes that operate in the attentional system are the engagement and disengagement processes (Clarke et al., 2013). The engagement process is the mechanism that initially orientates attention. This process is biased when it contributes to attention being selectively drawn towards negative compared to neutral information. The disengagement process is the mechanism that relocates selective attention away from focal information. This process is biased when the ability to relocate attention away from current focal information is selectively impaired when processing negative information in comparison with when it is processing neutral information. The attentional engagement and disengagement processes in healthy individuals favour threatening over neutral stimuli. Cisler and Koster (2010) proposed that everyone experiences early detection of threatening stimuli and difficulties ignoring negative distractors. Moreover, Cisler and Koster (2010) stated that individuals with anxiety demonstrate the same bias in the attentional processes, however, significantly larger in magnitude compared to healthy controls.

In order to gauge the extent to which changes in attention bias via ABM are achieved by modifying biased attentional engagement or disengagement, it is important to obtain baseline measures of these separate processes. As described in Chapter 1, some methodological difficulties were encountered when assessing the attentional engagement and disengagement processes. Clarke et al. (2013) proposed three criteria which are essential to disentangle the attentional engagement and disengagement process of selective attention. Firstly, the task needs to control for the systematic behavioural slowing of reaction-time unrelated to attentional processes (i.e., freezing) for anxious individuals in the presence of threat stimuli. This can be done by including control trials wherein threat and neutral stimuli are presented within an attended locus and no spatial movement of attention is required. Secondly, the task should include an initial fixation point before allowing subsequent attentional shifts. For the attentional engagement bias measure, attention should be equally often secured on emotional and neutral stimuli, before assessing relative

facility to shift attention towards this stimulus. For the attentional disengagement bias measure, attention should be initially equally often fixated on emotional and neutral stimuli, before assessing relative facility to shift attention away from this stimulus (Clarke et al., 2013). The third criterion holds that once initial fixation has been established, the task must allow assessment of the facility with which selective attention can be shifted in relation to emotional stimuli. This can be accomplished by including neutral baseline trials to which the speed of attentional shifting in relation to emotional stimuli can be compared to. Some prior studies did not include these features which limited the conclusions that could be drawn on the basis of these findings (Fox et al., 2001; Fox et al., 2002; Koster, Crombez, Verschuere, & De Houwer, 2004; Yiend & Mathews, 2001). Grafton and MacLeod (2014) as well as Rudaizky et al. (2014) designed and tested an attention process assessment (APA) task in line with these three criteria and found that both the engagement and disengagement process of attention can be biased independently, especially in those high compared to those low in trait anxiety.

### **The Attentional Process Assessment Task**

The attentional process assessment (APA) task assesses attentional engagement and disengagement with sixteen different trial types, for example trial see Figure 19. Each trial consists of a representational emotional (angry face) or neutral (neutral face) stimulus, always presented together with a non-representational abstract stimulus (facial silhouette). Initial attention is fixated with a cue probe, located equally often in the same location as the representational and non-representational stimuli, before the stimuli appear. Further, a target probe is presented in the same location, equally often as the representational and non-representational stimuli, after the stimuli appeared.

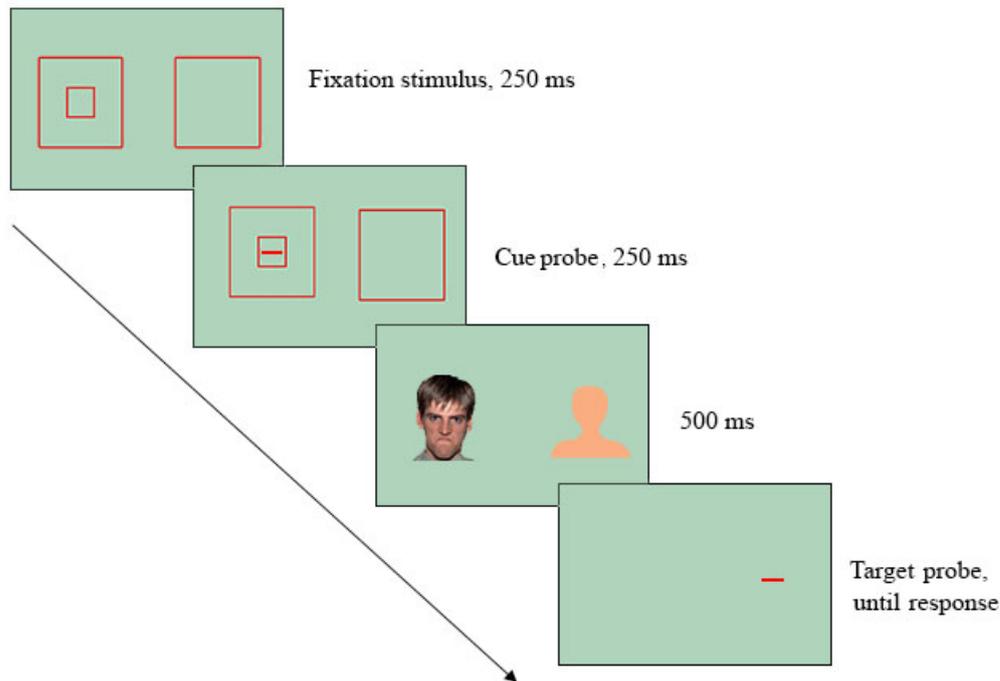


Figure 19. Example of a Trial on the Attentional Process Assessment Task. The probes used in the task were smaller. The trial displayed is a disengagement bias assessment trial. An angry face (the representational stimulus) and facial silhouette (the non-representational stimulus) are presented. Attentional focus is initially anchored in the same location as the representational stimulus with the cue probe. The target probe is presented in the opposite location from the representational stimulus, in the same location as the non-representational stimuli.

The first step involved the participants having to process a briefly presented cue probe that appeared in left or right screen location which then fixated their initial attention on that screen location. This enabled the presentation of the images of two different types of emotional expressions, either in the opposite location from, or the same location as the initial location of the cue probe. Then, by measuring the time taken by the participants to process a second probe, which appeared in the location of the representational or abstract image, it was possible to ascertain the degree to which attention became focused on the representational images located in the opposite location, compared to the degree to which attention remained focused on the representational images which remained in the same location as the initial fixation. This permits computation of an *attentional engagement bias index* that reflects the degree to which attention *becomes focused* to a greater extent on angry relative to neutral representational stimuli located in the opposite location as the initial fixation. Additionally, it allowed for the computation of an *attentional disengagement bias index* that reflects the degree to which attention *remains focused* on angry relative to neutral representational stimuli located in the same location as the initial fixation.

The APA task has been successfully used to assess both biased attentional engagement and disengagement related to anxiety with pictures from the International Affective Picture System (IAPS; Grafton & MacLeod, 2014; Rudaizky et al., 2014).

Employing the APA task, pre- and post-ABM training, allows for the investigation into whether engagement by emotion, disengagement from emotion, or both processes change in response to ABM. Furthermore, this design would permit the identification of the attentional processes responsible for bias change. This in turn can inform future researchers to target specific processes, which result in more precise ABM training. Moreover, it is a possibility that different ABM training tasks change different biased processes. Further understanding of the role of these processes in attention bias change could increase the efficacy of ABM training paradigms. In addition, the current study tested the attentional process change achieved with the gamified emotion-in-motion task against those achieved by the conventional dot-probe task. The APA task that previously used stimuli from the IAPS was modified to present facial stimuli to match the stimuli previously used in the emotion-in-motion task.

The present design will permit examination of the relative efficacy of the two different training tasks in achieving changes in each process and whether these different types of training lead to similar, or different changes in attention bias to facial information. The current study will determine whether changes in biased attentional disengagement are responsible for ABM induced changes in attentional bias (H1), whether changes in biased attentional engagement are responsible for ABM induced changes in attentional bias (H2), or whether a combination of the two processes are responsible for ABM induced changes in attention bias (H3). According to H1, ABM training away from threat will contribute to greater ease of disengagement from negative stimuli, while ABM training towards threat will lead to greater difficulty disengaging from such stimuli. According to H2, ABM training away from threat will contribute to greater ease of inhibiting engagement by negative stimuli, while ABM training towards threat will lead to enhanced engagement by such stimuli. According to H3, ABM training away from threat will contribute to greater ease of inhibiting engagement with, and disengagement from negative stimuli, while ABM training towards threat will lead to enhanced engaging with, and greater difficulty disengaging from such stimuli. Parallel to the above hypotheses, the

study design will be able to establish whether the dot-probe task induces the same or different attentional change in biased processes as the emotion-in-motion task (H4).

## Methodology

### Study Design

The study design was a pre- and post-test repeated measures design with three independent variables: Attentional Bias Type, Training Condition and Time. Two attentional bias types were assessed, the engagement and disengagement bias. The type of training was either the traditional dot-probe task (DPT) or the emotion-in-motion (EIM) task. The direction of training was either ‘attend-neutral’ or ‘attend-angry’. Hence, participants were randomly allocated to one of the four training conditions: (1) DPT-angry; (2) DPT-neutral; (3) EIM-angry; and (4) EIM-neutral. The dependent variables were the engagement and disengagement bias index calculated from RTs measured at two time points: pre- and post-training. State anxiety was measured at baseline to ensure group equivalence.

### Participants

One-hundred and fifty-one undergraduate students participated in exchange of course credit. They were randomly assigned to complete one of the four training conditions. Five participants were unable to complete all trials and fourteen made more than 30% of errors in the attentional process assessment task (pre-test only:  $n = 4$ ; post-test only:  $n = 3$ , in both:  $n = 7$ ). Hence, the final sample analysed consisted of 132 participants (98 female, 33 male and 1 endorsing another gender), who were aged between 17 and 48 ( $M = 22.5$  years,  $SD = 5.23$ ). Sixty-five participants completed the dot-probe task, of whom 35 were trained to attend to neutral and 30 to attend to angry faces. Sixty-seven participants completed the emotion-in-motion task, of whom 35 were trained to attend to neutral and 32 were trained to attend to angry faces. A post-hoc sensitivity test with GPower software (Faul, Erdfelder, Buchner, & Lang, 2009) showed that our sample size of 132 could find a small effect of  $d = 0.15$  ( $1 - \beta = .80$ ,  $\alpha = .05$ ) when conducting a repeated measures, within-between ANOVA with 4 groups and 2 measurements.

### Procedure

The Curtin Human Ethics Research Commission approved the study. All tasks were run on a computer with a screen resolution of 1920x1080. The dot-probe task and attentional process assessment task were controlled by custom-written software run under DMDX (Forster & Forster, 2003). The emotion-in-motion task

was provided by the CARE lab from the University of Western Australia and ran using BBC Basic software. Participants sat in a chair facing the monitor at a distance of approximately 60cm. Participants were tested with a maximum of four at a time in separate testing cubicles. On arrival, they were provided with an information sheet and completed the consent form. After providing their demographics, participants completed the state subscale of the State and Trait Anxiety Inventory (STAI-S). One-hundred and fourteen participants completed the rating task before starting the rest of the experiment, where participants rated all the facial stimuli used in subsequent tasks on valence and intensity. All participants completed the APA task that measured the attentional processes before they were randomly assigned to one of the four training conditions. After the training, participants completed the APA task again. The experiment finished with a debriefing, the entire procedure took approximately 90 minutes.

## **Materials**

### **Spielberger's State-Anxiety Inventory**

State anxiety was assessed with the 20-item state subscale of the Spielberger's State-Trait Anxiety Inventory (STAI-S; Spielberger et al., 1983). The STAI-S asks participants to indicate the degree to which participants are experiencing a variety of anxiety symptoms "at this moment". Scores on this subscale range from 20 to 80, with higher scores representing higher levels of state anxiety. STAI has been shown to have good reliability and validity (c.f. Grös et al., 2007). Our sample showed a Cronbach's alpha of .90, and a mean anxiety score of 31.2 ( $SD = 7.54$ , median = 29.0) that ranged between 20 and 60.

### **Stimulus Materials**

In all the attentional tasks, the same facial stimuli of an ethnic and gender diverse set was used (65% Caucasian, 25% Asian, and 10% African). This diverse stimulus set was chosen in this study to increase ecological validity. The total of 32 representational faces (16 female and 16 male) with a neutral and angry expression with closed mouth were chosen from the NimStim database (Tottenham et al., 2009). For the APA task, an additional 32 non-representational abstract faces were found with a Google search using the terms "Facebook profile silhouette" and were modified using Adobe Photoshop CC 2015 to match the representational faces in size and skin colour. The background colour of all faces was a soft blue/green colour (R:

176, G: 211 and B: 187) that matched the background colour of the APA task. All facial stimuli were sized at 320x320pixels.

All representational faces were checked for valence and intensity in a rating task prior to the start of the experiment. This was done to ensure that the stimuli represented the emotion as intended as well as that the intensity of the expressions were equal between stimuli. Participants conducted a simple categorisation task where every face would come up once and the participant had to press the 'A'-key when it was a neutral face and the 'L'-key when it was an angry face (this was counterbalanced across participants). Followed by a 1 to 9 rating of the intensity, with 1 being not intense at all to 9 being very intense.

### **Attentional Process Assessment Task with Facial Stimuli**

The attentional process assessment (APA) task was used to assess engagement and disengagement bias pre-and post-training (Grafton & MacLeod, 2014; Rudaizky et al., 2014). The task was modified into a face version, where angry and neutral facial expressions replaced the representational pictures of the IAPS, and the facial silhouettes replaced the abstract images of art that were used as non-representational stimuli. An example trial is displayed in Figure 19.

The task had sixteen different trial types, each presented twenty-four times, resulting in a total of 384 trials. Each trial started with two red frames (sized at: 320x320 pixels), which were presented on the left (x, y coordinates: 300, 380) and right side (x, y coordinates: 1110, 380) of the screen for 500ms. In one of the two frames a little box was presented (sized at 100x100 pixels). The cue probe, which was either a horizontally or vertically presented line (sized at 15x5 pixels) would appear in that box after 250ms. Participants were instructed to attend to the box and remember the orientation of the cue probe. Subsequently, two facial stimuli (representational face vs abstract silhouette) would appear for 250ms in the same location as the frames. The representational face consisted of a neutral or angry facial expression. Thus, there were two general trials, one where an angry face was paired with a silhouette (threat-trial) and one where a neutral face was paired with a silhouette (baseline trial). In a threat trial, RTs of attentional shifts are influenced by emotion, in the baseline trials, RTs function as a baseline measure of attentional shift without the presence of emotion. Finally, the target probe, which was the same as the cue probe (also horizontally or vertically presented), appeared either on the left or

right side of the screen and would stay on until a response was made. Participants needed to match the orientation of the target probe to the cue probe as quickly as possible without making any mistakes using the shift keys. That is, participants responded with the left shift key when the cue and target probes differed in their orientation and the right shift key when the orientation was the same (this was counterbalanced across participants). Participants were given two examples and six practice trials before the main task started. Given that participants required to process a briefly presented cue probe that initially appeared in either screen location, their attention is anchored in this location. Then, the APA task presented the angry or neutral face either in the same or opposite location of this initial fixation of attention. Next, timing how long the participant took to process the target probe, which appeared either in the same location of the representational (angry or neutral face) or abstract face (silhouette) determined the degree to which attention remains focused on the same located representational stimuli or becomes focused to the opposite representational stimuli. The data preparation section explains how the attentional engagement and disengagement index were calculated.

### **Attention Bias Modification Training Procedures**

Participants were randomly allocated to two types of training, half of the sample completed the conventional dot-probe ABM task and the other half completed the gamified emotion-in-motion ABM task.

*The Conventional Dot-Probe Task with Facial Stimuli.* Responses were collected on a QWERTY-keyboard with either the left and right shift key. The match between response key and probe was counterbalanced across participants. Every trial would start with a 500ms presentation of a fixation cross in the middle of the screen, followed by two facial expressions (angry and neutral) of the same poser presented next to each other for 500ms (960 pixels apart, measured from the centre of the stimuli). The facial stimuli used in the dot-probe task were the same as the stimuli used in the APA task. Then a probe, which was a small red line (15x5 pixels) either presented horizontally or vertically, would be presented in the location of one of the two faces, thus in the left or right location. Participants were instructed to respond as quickly as possible to the orientation of the probe, without making mistakes. The probe would disappear after a response was made or after 1500ms. The dot-probe task training procedure consisted of 384 trials with a 100% stimulus-probe

contingency to train selective attention to neutral or angry faces. For those in the ‘attend-neutral’ condition, the probe was always preceded by a neutral face and for those in the ‘attend-angry’ condition, the probe was always preceded by an angry face. Given that the training was one of 100% congruency, no data is available on the attention bias during training. Figure 23 in the Appendix at the end of this chapter shows the collated average RT over 16th dot-probe training trials per training condition. We decided to collate the RT of 16 trials into one average score and plot that instead of all single RTs of every 384 trials, as the graph would become too messy. The number 16 was chosen because 384 trials can be divided by 16, resulting in 24 dotted time points.

***The Gamified Emotion-in-Motion Task with Facial Stimuli.*** The emotion-in-motion task (see Figure 20) was designed to train selective attention toward or away from angry faces in a gamified setting (Notebaert et al., 2018) and a demo can be viewed on the web: <https://www.youtube.com/watch?v=PMUnimtCag0>. Eight frames that contained faces were presented on the screen, of which one was the target and seven were distractors. Participants in the ‘attend-angry’ condition were instructed to follow an angry facial expression (target) amid neutral distractor faces, while participants in the ‘attend-neutral’ condition were instructed to follow the neutral facial expression (target) amid angry distractor faces. All the frames, including the frame that presented the target, constantly switched identity. The emotional expression of the target, in addition to its identity, would change at random intervals, and one of the other frames would present a face depicting the target expression. This then became the new target. At these occurrences, participants had to find the new target as quickly as possible and start tracking it with their mouse again. Identical to Notebaert et al. (2018), each face remained constant for the first 2 seconds of each game. From then on, individual faces within a frame switched to a different identity, while keeping the same facial expression at any point between 1 and 2000 milliseconds throughout the game. Within each game, the target expression shifted to another frame 60 times, at random intervals of 5 to 10 seconds. All 8 frames moved on different randomly predetermined paths, at a randomly predetermined speed between 30 and 50 pixels per 100 milliseconds. Thus, although the frames moved at different speeds, each frame’s speed was constant within a game. The frames bounced off the screen limits and off other frames they contacted at the reflected angle of impact. The target was indicated by the emotional expression

of the face. Furthermore, the mouse only disappeared when the cursor was correctly located in the position of the current target frame, to not obscure the target expression.



*Figure 20. A print screen of the emotion-in-motion task*

Participants were instructed to play five games of 5 minutes each. Each game would start with a 3-second countdown presented in the centre of the screen. After every game, participants were given feedback in the form of a score that represented the proportion of time that participants had their mouse on the target face during the game, as well as the average time taken to shift the mouse to the next target when it had moved to another frame. These scores were displayed along with the higher score for each over the past games. Participants were furthermore instructed to try to break their own high score with each new game they played. Unfortunately, this task originally consisted of 8 games and was programmed in a way that it saved each participants' scores after the completion of all 8 games. It was decided to use only 5 games in this study to match the duration of training with the dot-probe task and to reduce load on participants. Unaware of the save protocol of the program, data was not stored for the five games that the participants played. Ten participants completed the full 8 games as they did not follow instructions, the data of these ten participants are shown in Table 18 of the Appendix.

### Data Preparation and Statistical Analyses

Two bias index scores were calculated from the sixteen different trial types in the APA task, these scores are presented at the end of this chapter in the Appendix Tables 17 and 18. The formula to calculate these bias index scores is shown in the footnote<sup>1</sup>. An attentional engagement bias index was calculated that reflected the degree to which attention becomes focused to a greater extent on angry relative to neutral faces, situated away from the initial fixation. An attentional disengagement bias index was calculated that reflected the degree to which attention remained focused on angry relative to neutral faces, situated in the same location as the initial fixation. As outlined in Rudaizky et al. (2014), a higher (positive) score on these bias indices represented selectively enhanced shifting of attention towards unattended faces that were situated away from initial fixation when these were negative rather than neutral (*greater engagement bias toward threat*) and a heightened tendency for attention to be sustained on faces that were presented in the same location as the initial fixation when these were negative rather than neutral (*greater difficulty disengaging from threat*). Scores around zero represent no engagement or disengagement bias. Lower (negative) score on these bias indices represented selectively enhanced shifting of attention towards initially unattended faces that were situated away from initial fixation when these were neutral rather than angry (*greater engagement bias away from threat*) and a heightened tendency for attention to be sustained on faces that were presented in the same location as the initial fixation when these were neutral rather than angry (*greater difficulty disengaging from non-threat*).

Before calculating the attentional bias indices from the mean RTs of every trial, the error trials were discarded. Errors were defined as an incorrect button press, failure to respond within 3000ms or an extreme score –values more than three standard deviations above or below the mean relative to each participant’s mean RT and were entered as missing values. Descriptive statistic on the proportion of errors in the pre- and post-attentional process assessment tasks are shown in Table 12. The means RT of each trial type were then checked to determine whether any of them were extreme scores. None of the scores were outside the 3SD range of the overall sample’s mean. In addition, participants were not excluded based on outlier bias scores after the engagement and disengagement bias index scores were calculated. This was similar to the data preparation procedure of Grafton and MacLeod (2014);

Rudaizky et al. (2014) who tested the APA task on smaller sample sizes with larger error variance and standard deviations. Thus, none of the participants were excluded in addition to those 15 participants who made more than 30% of errors.

Table 12.

*Descriptive Statistics on the Proportion of Errors made in the Attentional Process Assessment Task Pre- and Post-Training*

	Pre-Test			Post-Test		
	<i>n</i>	Range	<i>M(SD)</i>	<i>n</i>	Range	<i>M(SD)</i>
Total	149	2.08-65.9	12.3(11.1)	145	2.08-65.9	12.1(11.6)
Included	138	2.08-28.6	9.62(5.32)	135	2.08-19.2	9.38(5.51)
Excluded	11	33.3-65.9	45.7(10.5)	10	32.3-65.9	48.7(11.1)

*Note: Based on greater than 30% of errors, 7 participants were excluded in both the pre- and post- test, 4 participants only in the pre-test and 3 participants only in the post-test, resulting in the exclusion of 15 participants in total.*

Attentional engagement and disengagement bias index scores of the final 133 participants were entered in 2 x 2 x 2 x 2 Attentional bias type (engagement vs disengagement) by Time (pre vs post) by Training (DPT vs EIM) by Direction (attend-angry vs attend-neutral) ANOVA. Significance level for all analyses were set at  $p < .05$ .

## Results

### Face Ratings

One-way ANOVA's conducted on the mean intensity ratings and the mean reaction time needed to categorise facial stimuli as angry or neutral did not differ across training conditions, all  $F < 1.09$ ,  $p > .298$ , or levels of state anxiety (dichotomised with a median split), all  $F < 1.60$ ,  $p > .209$ . Descriptive statistics for each face used are shown in Table 15 of the Appendix. The mean intensity ratings for each training condition are reported in Table 13.

Table 13.

*Range, Mean and Standard Deviation of the Intensity Ratings for the Angry and Neutral Stimuli*

	Angry Faces		Neutral Faces	
	Range	<i>M(SD)</i>	Range	<i>M(SD)</i>
DPT-angry ( $n = 30$ )	1.00 – 7.86	4.86(2.69)	1.00 – 6.06	3.13(1.51)
DPT-neutral ( $n = 32$ )	4.31 – 8.47	6.50(.12)	1.00 – 7.75	2.22(1.63)
EIM-angry ( $n = 33$ )	3.94 – 7.81	6.37(1.00)	1.00 – 6.81	2.38(1.42)
EIM-neutral ( $n = 31$ )	4.81 – 8.31	6.48(0.96)	1.00 – 8.69	2.70(1.85)

The valence of each face was on average miss rated 4.45 times ( $SD = 4.42$ ,  $PE = 37.1$ ). As shown in Table 15 of the Appendix, the neutral and angry facial expression of one specific model was miss-classified by participants more often than

other models, 3.17 SDs and 4.53 SDs from the mean, respectively. All other models were miss rated  $< 2.5$  SD's from the mean. The trials with this model, therefore, were excluded from further APA analyses.

### State Anxiety and Attentional Engagement and Disengagement at Baseline

Descriptive statistics of the total STAI-S score of each training condition are shown in Table 14. A one-way ANOVA showed that state anxiety was trending towards a difference between the four training conditions,  $F(3,127) = 2.20, p = .091, \eta^2 = .049$ . Post-hoc comparisons (Bonferroni corrected) revealed that none of the training conditions significantly differed in their state anxiety scores at baseline, all  $t < 2.37, p > .114, d < 0.55$ .

Table 14.

*Descriptive Statistics on the Total State Anxiety Scores for each Training Condition*

	Range	$M(SD)$	Distribution ( $S, K$ )
DPT-angry ( $n = 30$ )	20 – 51	31.6(8.17)	.687, -.267
DPT-neutral ( $n = 32$ )	20 – 51	29.5(7.18)	1.06, 1.22
EIM-angry ( $n = 33$ )	20 – 60	33.9(8.65)	.934, 1.47
EIM-neutral ( $n = 31$ )	21 – 46	30.1(5.69)	.698, .410

*Note: Means ( $M$ ) and standard deviations ( $SD$ ) of those in the dot-probe task (DPT) and emotion-in-motion task (EIM), either trained to attend angry faces (-angry) or trained to attend neutral faces (-neutral). Standard errors of skewness ( $S$ ) was  $< .472$  and of kurtosis ( $K$ ) was  $< .833$ .*

At baseline, the sum score of the STAI-S did not correlate with the engagement bias,  $r(130) = .081, p = .359$  or with the disengagement bias measured at baseline,  $r(130) = .065, p = .461$ . The scatterplot in Figure 21 show the correlations between state anxiety and the engagement and disengagement bias index scores per training condition.

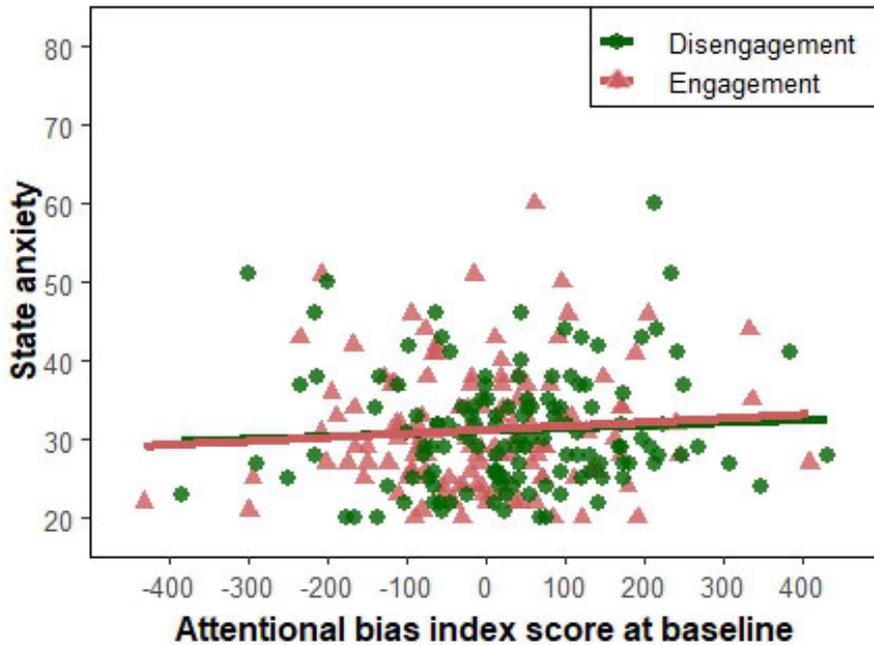


Figure 21. The Association between State Anxiety and Engagement and Disengagement Bias at Baseline. Negative scores indicate attention bias towards neutral faces, whereas positive scores indicate attention bias towards angry faces (Study 2). The lines represent the line that fits the data best.

**Changes in Attentional Processes in Response to Attention Bias Modification**

The engagement and disengagement bias index scores assessed pre-and post-training for each training condition are displayed in Figure 22.

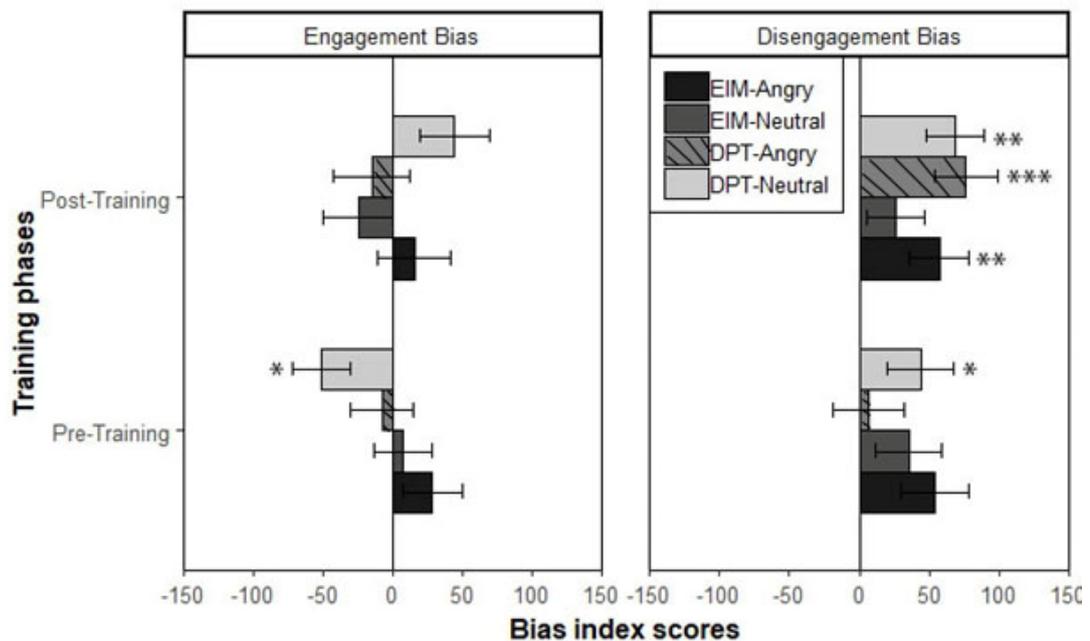


Figure 22. Attentional Engagement and Disengagement Bias towards Angry and Neutral Faces from Pre- and Post-Training Condition in Study 2. Positive scores indicate attention bias towards angry faces, whereas negative scores indicate attention bias towards neutral faces. Error bars represent standard error from each mean. \*\*\* =  $p < .001$  \*\* =  $p < .010$  \* =  $p < .050$  (significant difference from zero).

The ANOVA resulted in a significant main effect for Attentional Bias Type,  $F(1,128) = 17.3, p < .001, \eta^2 = .119$ , such that there was evidence to support the existence of an attentional disengagement bias towards angry faces ( $M = 46.3, SE = 7.99$ ), not for the existence of an attentional engagement bias ( $M = .050, SE = 8.05$ ). The interaction effect between Time and Training was significant,  $F(1,128) = 5.42, p = .021, \eta^2 = .041$ . Follow-up pairwise comparisons showed that the change from pre- to post-training was only significant for those who completed the dot-probe training task,  $t(64) = 2.55, p = .012, 95\%CI(10.3, 80.9), d = 0.32$ , that is, participants trained with the dot-probe task had no bias pre-training ( $M = -1.69, SE = 12.2$ ), however, had a tendency to attend more rapidly to and for an extended time with angry faces compared to neutral faces post-training ( $M = 43.9, SE = 12.1$ ). There was no significant change pre- to post-training for those who completed the emotion-in-motion training task,  $t(66) = .725, p = .470, 95\%CI(-22.0, 47.5), d = 0.18$ . It seems that the two different training task result in different attention bias change patterns.

Furthermore, the 4-way interaction between Attentional Bias Type, Time, Training, and Valence was marginally trending,  $F(1,128) = 2.89, p = .092, \eta^2 = .022$ . This was followed up for exploratory reasons. It seems that attention bias change in the disengagement bias was only significant in participants who completed the attend-angry training with the dot-probe task,  $t(29) = 2.06, p = .042, 95\%CI(2.60, 137), d = 0.54$ . As shown in Figure 22, these participants changed from having no attention bias pre-training to difficulty disengaging from angry faces post-training. This change is in the direction as expected based on the direction of training. Furthermore, attention bias change in the engagement bias was only significant in participants who completed the attend-neutral training with the dot-probe task,  $t(34) = 2.80, p = .006, 95\%CI(27.8, 162), d = 0.64$ . As shown in Figure 22, these participants changed from enhanced engagement with neutral faces pre-training to no bias post-training. This is in the opposite direction as expected based on the direction employed in training. However, all other comparisons in the 4-way interaction were not significant, all  $t < .945, p > .347, d < 0.27$ . This indicates that the training provided to participants did not result in consistent attention bias change in the direction of the training across the engagement and disengagement bias. Overall, there is no strong support for or against hypotheses and provided that this 4-way interaction was trending, it is more likely that the two significant comparisons are

based on chance. All other effects in the omnibus ANOVA were not significant, all  $F < 2.41$ ,  $p > .123$ ,  $\eta^2 < .018$ .

### **Discussion Study 2**

The objective of this study was to investigate how two processes that potentially contribute to attention bias -faster engagement with and the slower disengagement from threatening stimuli- change when two different attention bias modification (ABM) training tasks were employed. Furthermore, this study set out to compare the efficacy of the modification of attention bias patterns between the conventional dot-probe task and a novel gamified ABM procedure, the emotion-in-motion task. The results showed that participants trained with the dot-probe achieved a significant bias change from pre- to post-training and those trained with the emotion-in-motion task did not. However, the attention bias change induced in the dot-probe task was independent of what participants were trained to attend to. These results provide some support for H4, which explored the option that the dot-probe task and emotion-in-motion task provide different results when changing attentional bias processes.

The emotion-in-motion task, unlike the dot-probe task, was not successful in changing any attention bias processes. The bias change scores achieved with the emotion-in-motion training task in Notebaert et al. (2018) indicated that participants increased the correct tracking of happy faces with 2.7% from pre- to post-‘attend happy’ training. In Notebaert et al. (2018), this bias change score was assessed with an assessment version of the emotion-in-motion task. Since the two tasks are more dissimilar in this experiment, that is, the transfer was assessed from the emotion-in-motion task to the APA task, it is possible that the non-significant findings observed may have been due to the lack of far transfer. Besides, it is also possible that the emotion-in-motion task did not change attention bias. Given that the only significant bias change found in Notebaert et al. (2018) was in those trained to attend to happy faces, it is possible that the emotion-in-motion task does not change attention bias with attend to neutral or negative training conditions. Another possibility is that the game elements in the emotion-in-motion task may have distracted attention away from the learning mechanism that underlies successful attention bias change as suggested by Forman et al. (2018). The continuously moving and changing faces in the emotion-in-motion task may have disrupted learning.

There was a trend, which revealed that those trained to attend to neutral faces in the dot-probe task changed from enhanced engagement with neutral faces at baseline to no engagement bias post-training. The training direction had no effect on attention bias change, which was the opposite of what was hypothesised. Particularly, the engagement bias found with neutral faces at baseline in one condition seems odd given that attention and emotion theories (see Chapter 1) theorise that emotional stimuli capture attention more rapidly than neutral stimuli. Furthermore, participants in the dot-probe task who were randomised in the attend-neutral condition were the only ones who had an engagement bias towards neutral faces and a disengagement bias with angry faces at baseline, whereas participants in the other conditions revealed no attentional bias at baseline. It is possible that the significant effect found in this condition merely represents a random effect (i.e., regression to the mean). This failure of the randomisation process to produce equivalent groups at baseline is a limitation of this study. A second significant attention bias change was revealed by the exploratory follow-up analysis from the trending interaction. That is, those who completed the attention training to angry faces with the dot-probe task changed from no disengagement bias at baseline to an enhanced disengagement bias from angry faces post-training. This change is in the hypothesised direction, based on the training direction. However, similar to the previous significant pair-wise comparison, it is even more likely that this comparison emerged as a random chance rather than a true effect.

Overall, the results showed that the dot-probe training task changes attention bias towards angry faces, irrespective of the direction of training. Furthermore, the main effect of bias type was significant and revealed an overall disengagement bias with angry faces, while showing no evidence for an engagement bias. Hence, the bias change pre-to post-ABM with the dot-probe task was only evident in the attentional disengagement bias scores. In other words, the two training directions in the dot-probe task enhanced attentional disengagement with angry facial stimuli. It is challenging to explain why two different stimulus-probe contingencies that underlie learning of attention bias in the opposite direction would result in an attention bias in the same direction. Nevertheless, researchers have suggested that it is not the valence-specific change training (i.e., 'attend-neutral' training) per se that results in attention bias change, the non-valence-specific training (i.e., 'attend-angry' training) may also lead to an attention bias change (Yao et al., 2015). This is supported by

others who proposed that training in general enhances attentional control, in turn facilitating attention bias change (Chen et al., 2015). Thus, it is possible that attention bias is not merely changed through bottom-up stimulus-probe contingency learning (i.e., the training direction). Contingency learning irrespective of direction that results in attention bias change, may strengthen other higher-order processes, like attention control.

Future research is encouraged to investigate other processes than contingency learning that influence attention bias change. For instance, studies can assess attention control pre-and post-ABM to assess whether a change in attention control is associated with a change in attentional engagement and disengagement biased processes. Understanding the role of other processes like attention control in changing attention bias in ABM can shed light on how to successfully change attentional processes to change attention bias related to psychopathology. Moreover, it would be interesting to conduct this study using stimuli from the IAPS database and assess attentional engagement and disengagement bias pre- and post-different ABM training tasks. Given that the current study modified the APA tasks from an IAPS into a face version, the change in stimuli could have influenced the results.

### **Conclusion Study 2**

This research was the first to examine change pre- to post-ABM in the engagement and disengagement process of attention bias. The results showed that the dot-probe task and not the emotion-in-motion training task was successful in achieving a change in the attentional disengagement process. The dot-probe training task changed attention bias towards angry faces, irrespective of the direction of training. Furthermore this study did not replicate the findings of the first time the emotion-in-motion task was used (Notebaert et al., 2018). However, they used an assessment version of the same task to measure transfer, which was only significant in those trained to ‘attend-happy’. The change in stimuli used as well as the change in assessment task may explain why this experiment did not replicate the findings of the original. More research is needed to establish exactly what processes are changed in ABM and what conditions are necessary to successfully change both processes. This knowledge will provide control over attention bias change and facilitates the translation of ABM into clinical practice.

## Appendix Chapter 4

Table 15.

*Descriptive Statistics of Each Stimuli in the Face Rating Task, Including Mean RT, Standard Deviation and Number of Errors on the Valence Categorisation and Intensity Ratings in Study 2*

Model	Gender - Ethnicity	Valence Categorisation		Intensity Ratings	
		Mean RT(SD)	N Errors	Mean(SD)	Mean RT(SD)
Angry 1	Female - Asian	1948(1766)	3	5.57(2.21)	1641(1768)
Angry 2	Male - Caucasian	1678(1518)	1	6.65(2.21)	1555(1607)
Angry 3	Female - African	15638(969)	2	5.88(2.20)	1713(1741)
Angry 4	Female - Caucasian	2511(1904)	20*	3.90(1.88)	1480(1871)
Angry 5	Male - Caucasian	1638(1152)	1	7.19(2.24)	1684(1859)
Angry 6	Male - Caucasian	1963(2275)	5	5.85(2.20)	1574(1637)
Angry 7	Female - Caucasian	2043(1518)	8	4.41(2.00)	1665(2023)
Angry 8	Male - Caucasian	1554(912)	0	7.46(2.16)	1486(1750)
Angry 9	Female - Caucasian	1856(1240)	9	6.06(2.04)	1864(1901)
Angry 10	Male - Caucasian	1543(969)	4	6.87(2.10)	1442(1656)
Angry 11	Female - African	2049(1782)	5	7.08(2.28)	1594(1718)
Angry 12	Male - Caucasian	1811(1488)	3	5.86(2.23)	2033(2534)
Angry 13	Female - Asian	1608(1126)	2	6.71(2.19)	1605(1872)
Angry 14	Male - African	2084(1990)	1	5.08(2.12)	1903(2011)
Angry 15	Female - Caucasian	1688(1272)	2	6.12(2.23)	1568(1535)
Angry 16	Male - Asian	1854(1240)	2	6.31(2.25)	1996(2720)
Neutral 1	Female - Asian	1798(1011)	4	2.70(2.15)	1279(1130)
Neutral 2	Male - Caucasian	1560(1021)	3	2.58(2.10)	1177(1851)
Neutral 3	Female - African	1392(1012)	3	2.56(2.36)	861(1028)
Neutral 4	Female - Caucasian	1276(914)	14*	2.45(2.23)	748(731)
Neutral 5	Male - Caucasian	1367(818)	4	2.84(2.28)	980(1314)
Neutral 6	Male - Caucasian	1264(819)	2	2.68(2.00)	815(1126)
Neutral 7	Female - Caucasian	1296(1465)	9	2.46(2.97)	832(1223)
Neutral 8	Male - Caucasian	1193(939)	2	2.42(2.92)	749(834)
Neutral 9	Female - Caucasian	1523(1134)	11	2.95(2.95)	803(832)
Neutral 10	Male - Caucasian	1382(1134)	1	2.60(2.01)	868(2308)
Neutral 11	Female - African	1506(1190)	8	2.80(2.92)	726(762)
Neutral 12	Male - Caucasian	1108(817)	2	2.36(2.88)	706(828)
Neutral 13	Female - Asian	1095(761)	1	2.54(2.06)	646(727)
Neutral 14	Male - African	1178(817)	1	2.54(2.10)	772(1129)
Neutral 15	Female - Caucasian	1175(1086)	3	2.37(2.92)	635(759)
Neutral 16	Male - Asian	1481(1592)	5	2.72(2.88)	666(788)

*Note: Mean reaction times (RT) and standard deviation (SD) and number (N) of errors for the valence categorisation of each face. Each face was rated by 114 participants.*

*Mean RT and value, including their standard deviation (SD) of the intensity ratings of each face.*

*\* Trials with this model were deleted from the analysis due to high miss ratings in terms of its valence.*

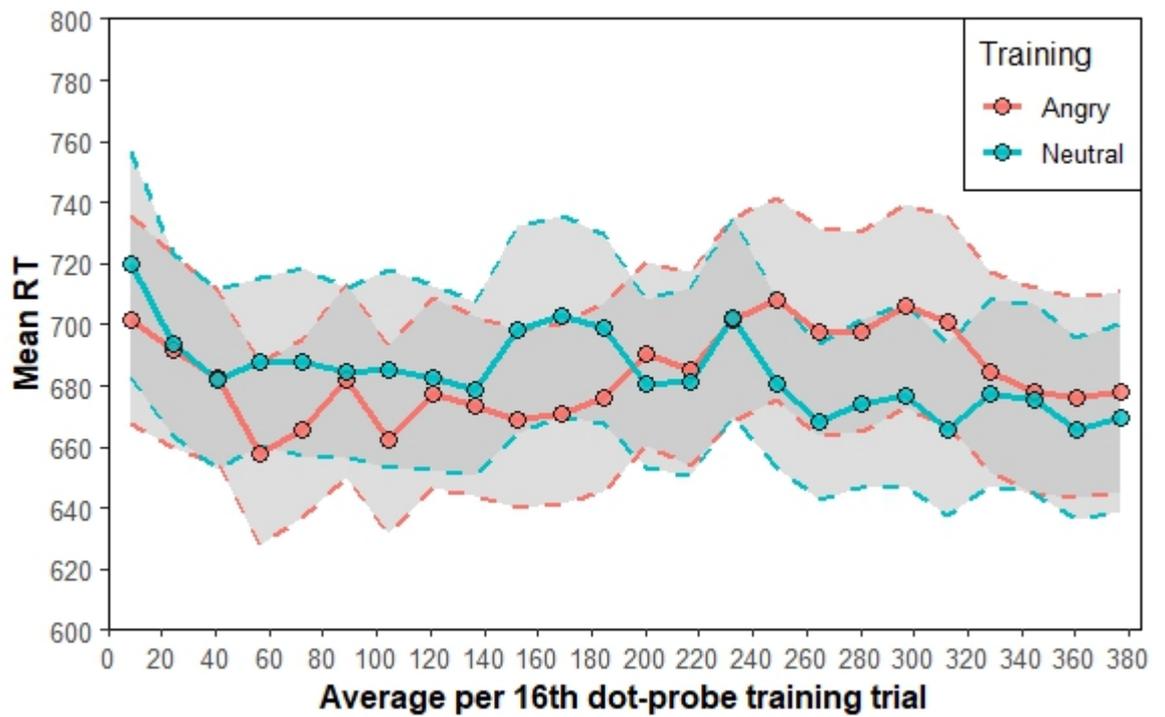


Figure 23. Mean RT and 95% Confidence Interval (dotted lines) per 16th Dot-Probe Training Trials for the 'Attend-Angry' and 'Attend-Neutral' Training Condition in Study 2.

Table 16.

*Mean Tracking Percentage and Mean Reaction Time per Emotion-in-Motion Game and Averaged across all Games for those Participants that completed all Eight Games.*

		Game 1	Game 2	Game 3	Game 4	Game 5	Game 6	Game 7	Game 8	Average
'Attend-Neutral' ( <i>n</i> = 5)	<i>M</i> <sub>tracking</sub> (%)	35.2	42.6	45.7	25.7	47.2	41.4	37.6	39.2	39.3
	<i>M</i> (RT)	3.26	2.95	2.97	3.22	2.67	2.77	2.86	3.03	2.967
'Attend-Angry' ( <i>n</i> = 5)	<i>M</i> <sub>tracking</sub> (%)	32.4	35.6	42.3	30.1	40.0	37.0	35.2	38.4	36.4
	<i>M</i> (RT)	3.27	2.94	2.74	2.88	2.79	2.65	2.62	2.93	2.855

*Note: Participants were instructed to complete only 5 out of 8 games, therefore, most data was not saved. Data shown in this table belongs to 10 participants that did not follow instructions.*

Table 17.

*Reaction Time (Standard Deviations) and Distributions of all Trial Types in the those that Completed the Emotion-in-Motion Task in Study 2*

		Attend-angry						Attend-neutral					
		Initial fixation location	Target cue location	Screen location representational face	Pre-Training $M(SD)$	Post-Training Distribution (S, K)							
1	Engagement	Left	Left	Right	789(56.26)	.095, .086	682(75.5)	.435, -.299	798(81.6)	-.097, -.531	699(62.1)	.399, -.151	
2	threat trials	Right	Left	Left	834(57.0)	.145, .238	746(68.5)	.433, -.187	857(54.9)	-.022, -.822	740(61.7)	-.264, 2.32	
3	(angry-	Left	Right	Right	776(53.8)	.312, -.303	688(61.6)	.056, -.011	791(63.4)	-.291, .540	677(73.9)	.768, .764	
4	silhouette pair)	Right	Right	Left	818(64.4)	1.15, 1.94	692(58.5)	-.770, 2.16	804(60.0)	.044, -.096	685(51.2)	-.027, -.417	
5	Engagement	Left	Left	Right	789(77.0)	.475, .298	678(67.4)	.447, .089	811(63.4)	.220, -.091	694(52.0)	.394, .784	
6	baseline trials	Right	Left	Left	833(61.8)	.150, .700	734(62.3)	.246, .003	834(59.2)	-.732, 1.08	760(49.4)	.235-.558	
7	(neutral-	Left	Right	Right	806(57.5)	.698, 1.12	687(71.2)	.514, -.837	777(53.7)	-.117, .209	667(70.4)	.508, .079	
8	silhouette pair)	Right	Right	Left	810(79.9)	1.62, 6.39	670(63.5)	.462, 1.01	799(49.1)	.100, -.507	663(50.3)	.199, .081	
9	Disengagement	Right	Left	Right	759(67.8)	-.722, .367	676(78.7)	-.401, -.169	754(73.8)	-.035, .205	675(55.7)	-.205, .121	
10	threat trials	Left	Right	Left	762(63.0)	.501, .867	670(64.0)	.532, .104	749(52.2)	-.676, 2.77	637(51.5)	.046, -.186	
11	(angry-	Left	Left	Left	912(64.1)	.219, -.891	774(62.8)	-.124, -.271	917(87.9)	.384, .237	800(77.4)	.537, .518	
12	silhouette pair)	Right	Right	Right	821(64.9)	.252, -.443	688(74.3)	.418, -.536	812(71.5)	-.348, -.379	677(55.8)	-.529, .792	
13	Disengagement	Right	Left	Right	747(68.5)	-1.33, 3.69	667(69.7)	-.607, .749	759(64.9)	-.165, .389	678(65.3)	-.015, -.098	
14	baseline trials	Left	Right	Left	745(57.4)	.241, -.163	670(63.5)	.462, 1.01	746(56.3)	.265, -.378	663(50.3)	.199, .081	
15	(neutral-	Left	Left	Left	906(83.8)	-.074, -.445	789(57.5)	.318, .376	924(83.8)	.752, 1.58	816(75.3)	-.093, -.351	
16	silhouette pair)	Right	Right	Right	856(77.6)	.317, .617	729(56.2)	-.336, -.291	842(56.3)	.669, .224	719(56.3)	-.552, .530	

*Note: Baseline trials consisted of a neutral-silhouette face pair; threat trials consisted of angry-silhouette face pair.*

*The Initial fixation in engagement trials is always in the same location as the silhouette face; the initial fixation of disengagement trials is always in the same location as the angry or neutral face<sup>1</sup>.*

Table 18.

*Reaction Time (Standard Deviations) and Distributions of all Trial Types in the those that Completed the Dot-Probe Task in Study 2*

						Attend-angry				Attend-neutral			
		Initial fixation location	Target cue location	Screen location representational face	Pre-Training		Post-Training		Pre-Training		Post-Training		
					<i>M(SD)</i>	Distribution ( <i>S, K</i> )	<i>M(SD)</i>	Distribution ( <i>S, K</i> )	<i>M(SD)</i>	Distribution ( <i>S, K</i> )	<i>M(SD)</i>	Distribution ( <i>S, K</i> )	
1	Engagement	Left	Left	Right	802(50.6)	.100, .121	712(60.3)	-.405, 1.81	791(80.7)	.033, .579	699(72.4)	-.077, -.301	
2	threat trials	Right	Left	Left	837(79.0)	.464, .546	736(73.4)	-.041, -.173	822(56.3)	.579, .667	743(71.7)	1.84, 4.77	
3	(angry-	Left	Right	Right	787(60.7)	.000, .902	665(44.1)	.101, -.033	789(69.9)	2.00, 6.36	657(64.2)	-1.14, 2.97	
4	silhouette pair)	Right	Right	Left	790(68.7)	1.73, 5.21	692(64.8)	.024, .903	813(50.2)	.885, 1.07	689(71.4)	-.758, .480	
5	Engagement	Left	Left	Right	800(92.4)	-.286, 3.12	722(60.3)	.349, -.147	803(51.5)	-.065, .212	700(64.6)	-.052, 1.08	
6	baseline trials	Right	Left	Left	840(76.0)	.079, -.622	727(61.9)	-.203, .545	837(80.3)	1.88, 6.77	739(56.9)	.696, .548	
7	(neutral-	Left	Right	Right	777(47.3)	.838, .438	664(55.2)	-.116, .978	767(46.2)	.665, .284	689(64.6)	-.136, -.115	
8	silhouette pair)	Right	Right	Left	795(62.6)	1.89, 6.50	614(40.1)	.542, 1.38	808(74.2)	.079, 1.35	637(58.6)	-.377, .237	
9	Disengagement	Right	Left	Right	741(66.5)	-1.01, 1.72	683(48.2)	-.446, -.636	761(77.2)	-.440, .381	986(75.2)	1.34, 5.76	
10	threat trials	Left	Right	Left	749(44.0)	.732, .480	648(47.6)	-.607, .203	772(59.8)	.782, .727	666(54.7)	.403, -.569	
11	(angry-	Left	Left	Left	918(85.1)	-.335, 1.41	798(67.7)	.284, 1.58	913(84.5)	.095, .966	807(70.8)	.018, .413	
12	silhouette pair)	Right	Right	Right	837(88.4)	1.39, 4.60	700(58.3)	-.334, .185	823(84.8)	-.554, .055	685(80.3)	-.260, .297	
13	Disengagement	Right	Left	Right	755(60.8)	-.788, 1.70	683(54.3)	-.305, -1.78	763(66.0)	.002, -1.11	681(82.6)	1.60, 3.77	
14	baseline trials	Left	Right	Left	754(66.5)	2.47, 9.04	614(40.1)	.542, 1.38	743(71.8)	.336, 1.33	637(58.6)	-.377, .237	
15	(neutral-	Left	Left	Left	913(71.4)	-.232, -.180	804(85.2)	1.69, 5.01	909(77.5)	1.18, 3.02	801(59.6)	.197, .630	
16	silhouette pair)	Right	Right	Right	874(91.5)	1.78, 4.41	733(70.4)	1.13, 3.36	846(80.1)	-.505, .616	712(77.3)	-.457, 3.86	

*Note: Baseline trials consisted of a neutral-silhouette face pair; threat trials consisted of angry-silhouette face pair.*

*The Initial fixation in engagement trials is always in the same location as the silhouette face; the initial fixation of disengagement trials is always in the same location as the angry or neutral face<sup>1</sup>.*

## Footnote

<sup>1</sup> The engagement and disengagement bias index scores can be calculated from the mean trials reported in Table 16 and 17 of the Appendix by using the following formula:

*Engagement bias index =*

$$\frac{\text{Sum (threat trials without attentional shift)} - \text{Sum (threat trials with attentional shift)}}{\text{Sum (baseline trials without attentional shift)} - \text{Sum (baseline trials with attentional shift)}}$$

Engagement bias index (only RTs from engagement threat and baseline trials are used) = (When initial fixation is away from angry face in threat trial: RT for target cue location away from angry face *minus* RT for target cue location on angry face) minus (When initial fixation is away from neutral face in baseline trial: RT for target cue location away from neutral face *minus* RT for target cue location on neutral face).

*Disengagement bias index =*

$$\frac{\text{Sum (threat trials with attentional shift)} - \text{Sum (threat trials without attentional shift)}}{\text{Sum (baseline trials with attentional shift)} - \text{Sum (baseline trials without attentional shift)}}$$

Disengagement bias index (only RTs from disengagement threat and baseline trials are used) = (When initial fixation is on angry face in threat trial: RT for target cue location away from angry face *minus* RT for target cue location on angry face) minus (When initial fixation is on neutral face in baseline trial: RT for target cue location away from neutral face *minus* RT for target cue location on neutral face).

Chapter 5

**General Discussion**

The central purpose of this thesis was to investigate how attention bias is assessed, acquired and changed in an attention bias modification (ABM) paradigm based on the dot-probe task. Two main studies were conducted (see for overview Table 19). The first study investigated the main stimulus-probe associative learning mechanism of the dot-probe task. The second study investigated how different training tasks employed in the ABM paradigm change the attentional processes of engagement and disengagement. The results obtained by each study will be reviewed in turn below.

Table 19.  
*Overview of the Experiments Conducted in this Research Project*

Experiments	Study Design	DPT Stimuli	Probe duration	Software	Sample	Self-report
<b>Study 1</b>						
Experiment 1	ATATA	shapes	1500ms	DMDX	Students	Awareness
Experiment 2	TATA	shapes	1500ms	DMDX	Students	Awareness
Experiment 3	TATA	shapes	500ms	Inquisit	M-Turk workers	Awareness
Experiment 4	ATATA	faces	500ms	Inquisit	M-Turk workers	Awareness, SIAS, SPS
Experiment 5	ATA-AC	faces	700ms	Inquisit	M-Turk workers	Awareness, SIAS, SPS, STAI-S/T
<b>Study 2</b>						
Experiment 1	APA-T-APA	faces	5000ms	DMDX	Students	Face intensity and valence

*Note: A = dot-probe assessment task; T = dot-probe training task; APA = attentional processes assessment task; AC = Attentional Control assessment; SIAS = Social Interaction Anxiety scale; SPS = Social Phobia scale; STAI-S/T = State and Trait Anxiety Inventory.*

**Review of Research Findings in Study One: The Establishment of a Template for Understanding Attention Bias Change with the Dot-Probe Task**

The unpredictable and predictive stimulus-probe associations in the dot-probe task underlie assessment and training of attention bias, respectively. In the dot-probe task, two stimuli are briefly presented simultaneously on two locations of the screen. Afterwards, a probe is presented in one of the two locations. The association between one of the stimuli and the probe is established by presenting a probe in the same location as a certain stimulus category. In this research project, the stimulus-probe

association in the dot-probe assessment task was of 50% congruency. The probe was presented equally often in the location of both stimulus categories (i.e., certain shape or valence). Thus an attention bias was evident when participants responded quicker to probes that followed one stimulus category compared to probes that followed the other stimulus category. This is because selective attention was at the location of that stimulus at the time the probe was presented, decreasing the RTs on such trials. Selective attention needed to shift to the probe that was presented in the opposite location, increasing the RTs on those trials.

In the dot-probe training task the stimulus-probe association was of 95% congruency. The probe was presented in the same location as one of the two stimulus categories in 95% of the trials. Thus evidence of attention bias acquisition is demonstrated when individuals responded quicker to probes that followed the predictive stimulus compared to probes that followed the unpredictable stimulus. Such a pattern is taken as an indication that participants have learned the predictive function of a certain stimulus on the location of the probe, in other words, they learned the stimulus-probe contingency. As such, it would be revealed that these participants directed their selective attention to the location of the congruent stimulus. This would be indicated by a decrease in the RTs on 95% of the congruent trials as well as by an increase in the RTs on 5% of the incongruent trials as selective attention needed to shift to the probe that was presented in the location of the incongruent stimulus. As a result, the magnitude of the attention bias index (RTs on incongruent trials minus RTs on congruent trials) will be increased. Furthermore, the malleability of attention bias was assessed by providing a second training phase wherein the stimulus-probe contingency was reversed. A change in attention bias would be uncovered when participants acquired the attention bias during the training phase and as a result showed different attentional patterns in the assessments post-compared to pre-training phases. A within-training assessment was included to test whether attention bias acquired in training transferred to the post-training assessment phase as predicted by associative learning accounts (Le Pelley, 2004; Mackintosh, 1975). The within-training assessment was established by calculating an attention bias index score from the 95% congruent and 5% incongruent trials.

As reviewed in the introduction, recent research showed that providing a predictive stimulus-probe contingency in a training phase did not always lead to a successful attention bias change pre- to post-training phase (Grafton et al., 2017;

MacLeod & Clarke, 2015). Therefore, in Study 1 of this research project, five experiments were conducted to test how a stimulus-probe contingency in the dot-probe task can influence attention bias acquisition and change. In the first three experiments, non-emotional stimuli (black outlined circle and triangle shapes with a white fill) were used to establish a working template of the dot-probe task without the interference of individual differences that are evident when responding to emotional stimuli. In the final two experiments, emotional stimuli (angry and neutral facial expressions) were re-introduced to examine the effects of different stimulus-probe contingencies on changing attentional bias in relation to emotional information. Furthermore, the influence of individual differences in contingency awareness, anxiety vulnerability and attentional control on attention bias acquisition, change and assessment was investigated. Each experiment varied in its design and/or task parameters to determine a template for understanding changes in biased attention by establishing a dot-probe task capable of training, changing, and assessing an attention bias.

### **Attention Bias Acquisition Established in the Reversed, not in the Initial Training Phase**

The results of Experiment 1 demonstrated that attention bias was acquired in the second, not in the first training phase. To account for the lack of attention bias acquisition in the first training phase it was hypothesised that pre-exposing participants to a non-predictive stimulus-probe association at baseline prior to the first training phase, may have diminished learning of the contingency (Baker & Mackintosh, 1979; Lubow & Moore, 1959; Mackintosh, 1975). Experiment 2 sought to address this hypothesis by deleting the baseline assessment. However, no support was found for this hypothesis, as the findings of Experiment 2 replicated the findings of the first experiment (i.e., lack of attention bias in the first training phase, while attention bias was successfully acquired in the second training phase).

Experiment 3 was designed to address the possibility that the simplicity of the task may have meant that attention bias was not induced in the first training. It was hypothesised that by increasing the difficulty of probe identification, the reliance on the preceding stimuli would increase and in turn direct selective attention to the stimuli and enhance the chance that participants would learn the stimulus-probe associations. The probes were decreased in size and the probe duration was shortened. However, no support was found for this explanation in Experiment 3

wherein the dot-probe task was modified to increase the difficulty level of the dot-probe task. There was no evidence of attention bias change during training. Furthermore, in contrast to Experiment 1 and 2, attention bias was not acquired in either training phases. This implies that in contrast to what was hypothesised, learning of the stimulus-probe contingency was impaired with the more difficult dot-probe task.

### **Attention Bias Change only Visible within Training, not in Post-Training Assessment**

In accordance with attentional theories of associative learning (Kruschke, 2003; Le Pelley, 2004; Mackintosh, 1975) it was hypothesised that any pattern of selective attention assessed within a training phase would continue to be evident during the subsequent post-training assessment phase. If this were the case, participants would react faster to probes that presented in the same location as stimuli that previously held predictive value. However, no support was found for this hypothesis across the three experiments when the stimulus-probe contingency changed from a predictive contingency in the training phase, to a non-predictive contingency in the assessment phase. The bias index scores were not significantly different from zero in the assessment following the successful training phase. These results are in line with those of Le Pelley et al. (2013), who found that the predictiveness of a stimulus generated in a previous task was quickly extinguished and did not yield significant differences in a subsequent dot-probe assessment task. As such, the current results clearly suggest that the post-training assessment of attention bias is unlikely to precisely represent the pattern of bias acquired during the training phase, because the assessment phase will change the pattern of bias.

### **The Effects of Including Emotional Stimuli into the Template**

Experiments 4 and 5 discussed in Chapter 3 were designed to replicate the first 3 experiments with the inclusion of emotional stimuli. Emotional stimuli increase the probability of automatically capturing selective attention in the dot-probe task compared to non-emotional stimuli. In contrast to the previously used non-emotional stimuli, it was hypothesised that attention was likely to be biased at baseline to stimuli with emotional content. There are several individual difference variables that play a role in the existence and magnitude of pre-existing attention bias to emotional stimuli. First, the likelihood of finding an attention bias increases in samples that have elevated levels of anxiety vulnerability compared to those with

lower levels of anxiety vulnerability (MacLeod et al., 2019). Previous studies have consistently reported that individuals high in state and trait anxiety (e.g., Leleu, Douilliez, & Rusinek, 2014; MacLeod & Mathews, 1988; Mansell, Ehlers, Clark, & Chen, 2002; Mogg et al., 1994; Penf, Yang, & Luo, 2013) and social anxiety (e.g., Mansell et al., 2002; Pishyar et al., 2004; Wabnitz et al., 2016; Wong & Rapee, 2016) show heightened attention bias to emotional stimuli compared to those low in state, trait or social anxiety. Furthermore, the relevance (Pergamin-Hight et al., 2015) as well as the threat intensity of emotional stimuli (Koster et al., 2006) seems to influence the magnitude of the attention bias found. That is, negative attention bias in emotionally vulnerable individuals is enhanced when stimuli are disorder relevant and moderate in threat intensity.

Experiments 4 and 5 replaced the non-emotional shapes with facial stimuli and controlled for individual differences in emotional vulnerability with anxiety measures (social anxiety in Experiment 4 and social, trait and state anxiety in Experiment 5). Emotional stimuli used were angry faces of middle-aged Caucasian males, which were compared to neutral faces of the same models. In Experiment 4, the stimulus-probe contingencies of the dot-probe task were manipulated in the same way as was done in the previous three experiments. That is, attention bias acquisition was assessed with a training phase that trained selective attention to one of the two facial expressions, followed by an assessment. Then, attention bias change was assessed with a second training phase that reversed the contingency to change attention bias to the second, previously incongruent stimulus, followed by an assessment. The pre-, post-, and within-training assessments were included to assess whether attention bias was changed from pre- to post-training, as well as whether the attention bias acquired in the training phase was transferred to the post-training assessment phase. Furthermore, the training direction was counterbalanced between participants, which resulted in participants who were first trained to attend to angry, then neutral faces (labelled as AN) or the reversed (labelled NA). In experiment 5, the ABM paradigm was simplified by omitting the reversed training phase and its post-training assessment. There were two training directions, participants were trained to selectively attend to angry faces (labelled as 'attend-angry' condition) or to selectively attend to neutral faces (labelled 'attend-neutral' condition). In both experiments, the results of participants in the two training conditions were compared to a control group in which participants completed the same number of trials as the

experimental group, however, the stimulus-probe contingency consisted of 50% congruency throughout the whole procedure.

### **No Pre-Existing Attention Bias to Emotional stimuli at Baseline**

As reviewed in the beginning of the Introduction chapter, attention and emotion theories state that selective attention is biased towards emotional stimuli. An attention bias towards negative facial information is systematically found in individuals high in social anxiety (Duque & Vázquez, 2015). However, in both experiments that used emotional stimuli, the dot-probe task did not provide evidence for a pre-existing attention bias to angry faces compared to neutral faces in the total sample or in those high in social anxiety. A possibility is that there is no preferential attending to one or the other stimulus in our sample, because participants are effectively dividing their attention across both stimuli. Eye-tracking data has provided evidence for heightened vigilance for emotional faces in those with affective disorders (Armstrong & Olatunji, 2012). Given that our sample was not pre-selected on high vs low levels of social anxiety, it is possible that the dot-probe task was not able to detect an association with preferential attentional processing of angry vs neutral faces. Furthermore, attention bias tends to be demonstrated in between-group comparisons rather than correlations (Bantín et al., 2016).

An alternative is that the processing of stimuli with emotional content is not entirely automatic and the faces presented in the dot-probe task may be suppressed. Pessoa, Kastner, and Ungerleider (2002) showed with amygdala responses to negative facial stimuli that these stimuli were not automatically processed, but required volitional attention. The amygdala has shown to be critical in emotional processing (e.g., Anderson & Phelps, 2001). Pessoa et al. (2002) measured fMRI responses evoked by pictures of faces with fearful, happy, or neutral expressions combined with different oriented bars in the top left and right corner. In alternating blocks, participants were either instructed to attend to these faces and categorise them on sex ('attended' trials) or attend to the bars and decide whether the two bars were oriented in the same or different orientation ('unattended' trials). Pessoa et al. (2002) found higher activation of the amygdala in the 'attend-negative' relative to 'attend-neutral' facial stimulus conditions. They found no increased amygdala activation to the non-attended negative relative to neutral facial stimuli. In addition, Gaspelin and Luck (2018) found that individuals may be suppressing the salient stimuli like faces if they are not task relevant. Given that the faces in the dot-probe

task are not task relevant, the lack of attention bias at baseline in experiments 4 and 5 may be due to the lack of attention paid to the face stimuli. Participants may not have attended to the stimuli, even suppressed them, and as a result, the RTs were not influenced by the stimuli when participants needed to decide whether the probe was horizontally or vertically presented.

### **Attention Bias Acquisition and Change in Training was not Established**

In experiments 4 and 5, participants did not acquire an attention bias to neutral or angry faces when they received a 95% stimulus-probe contingency towards the neutral or angry face in the training phase, respectively. It seems that continuously associating the probe with a certain stimulus category is not enough to change selective attention to emotional or neutral stimuli. Given that this did not replicate the findings in the first three experiments, which used non-emotional stimuli, it is possible that the inclusion of emotional stimuli limited contingency learning, and subsequently attention bias acquisition. Given that emotional stimuli are more complex to process compared to black and white circles and triangles, it is possible that the complexity of the stimuli decreased contingency learning. The complexity of the stimuli may have led participants to ignore them, as it is possible to complete the dot-probe task without paying attention to the stimuli. Merely increasing the probe exposure duration by 200ms and omitting the second training and assessment phase, as done in Experiment 5, did not lead to the acquisition of attention bias. This suggests that decreasing the overall difficulty level of the task and procedure did not aid the acquisition of attention bias. It seems that other factors besides emotion or complexity of the stimuli interfere with the establishment of stimulus-probe associations that lead to attention bias acquisition and change.

It is likely that the explanation for the lack of attention bias to emotional stimuli at baseline can also explain the lack of training. Explicitly, the stimuli and, with them, the emotional valence were not automatically processed as participants may not have paid attention to the stimuli to detect the probe in training. Pessoa et al. (2002) reported that if attentional resources are depleted, face stimuli, emotional or not, will not be processed. This explanation is in line with self-reports of participants who completed experiments 4 and 5. Participants reported that they found the task very difficult to complete and were not aware of the role the stimulus played in the task. Overall, the results of the two experiments that included emotional stimuli indicated that attention bias was not evident in emotional compared to neutral stimuli

in the dot-probe task. It is possible that this finding was evident because some participants ignored all stimuli and only paid attention to the probes to complete the task.

Participants' failure to attend to the stimuli in the dot-probe task may explain why the dot-probe did not detect any pre-existing bias or change attention bias. Without attention paid to the stimuli that predicts the probe, participant's RTs are not influenced by biased attention at baseline or during training. Studies on the role of attention in stimulus-probe associative learning suggest that the association between a stimulus and an outcome is not established if they were paired in the presence of a second stimulus that has previously been associated with that outcome (Luque, Vadillo, Gutiérrez-Cobo, & Le Pelley, 2016). This effect has been labelled 'blocking' and was first documented by Kamin (1969). According to attentional models of associative learning, blocking reflects a decrease in attention paid to the blocked stimulus, resulting in the lack of contingency learning (Mackintosh, 1975; Rescorla & Wagner, 1972). Given that the dot-probe task presents two stimuli simultaneously of which a participant needs to learn the association with one stimulus and the probe, while the other stimulus was previously paired with the probe, it is possible that blocking occurs and hinders contingency learning.

### **The Effect of Individual Differences in Contingency Awareness on Contingency Learning**

Contingency awareness has shown to be a factor that is a requisite for contingency learning (Lovibond & Shanks, 2002) and was assessed in all five experiments of Study 1. In each experiment that used non-emotional stimuli, approximately one-third to half of the participants reported some awareness of a stimulus-probe association. The awareness data of these three experiments were combined into one analysis. This was done to ensure that the analysis was powerful enough to establish whether those classified as aware compared to those not aware would show different attention bias patterns during the assessment and training phases. The analysis showed that the attention bias acquired in the second training phase interacted with contingency awareness. Those reporting awareness of a stimulus-probe association showed quicker responding to the probe that followed the predictive stimulus, which indicated greater training of selective attention. No attention bias change in line with the contingency was evident in participants not aware of the stimulus probe contingency. The interaction between contingency

awareness and attention bias acquisition supports the strong single-process model of learning (Brewer, 1974). This model proposes that contingency awareness is a necessary step in contingency learning.

The inclusion of emotion in the design initially resulted in very few participants who reported awareness of the stimulus-probe contingency in Experiment 4 (<10%). After reducing the difficulty level of the dot-probe task, by increasing the probe duration by 200ms, and eliminating the reversed training and assessment phase, more participants reported awareness in Experiment 5 (40%). This suggests that contingency awareness may be dependent on the difficulty level of the dot-probe task. Nevertheless, in contrast to the previous three experiments that used non-emotional stimuli, the interaction between contingency awareness and attention bias acquisition was not replicated with emotional stimuli. It is likely that the awareness analysis was underpowered. Another explanation is that participants may have ignored the stimuli and only paid attention to the probes to perform the dot-probe task in experiments 4 and 5. This is supported by several researchers who have studied stimulus-probe associative learning in the dot-probe task with stimuli putatively below the threshold of conscious recognition. These studies showed that attention bias assessment and training is unlikely with the dot-probe task when the stimulus was presented below perceptual threshold (<170ms) (Bantin et al., 2016; MacLeod et al., 2002), indicating that the conscious perception of stimuli is necessary for contingency learning to occur.

Similar to our study, the first experiment reported in Grafton et al. (2014) measured awareness with self-report. They found that 21.9% of participants were able to freely recall the contingency and 37.5% after they were given multiple options to choose from. Grafton et al. (2014) found that the contingency training resulted in attention bias change in the trained direction. Although, the small number of participants acquiring awareness in the first experiment of Grafton et al. (2014) meant that the analysis was underpowered, this training effect was marginally greater in those aware when compared to those not aware. Furthermore, the change in attention bias did not result in differential emotional reactivity in those aware vs not aware after a stressor task. However, this effect was evident in the total sample. The second experiment of Grafton et al. (2014) as well as another recent study conducted by Lazarov et al. (2017) manipulated awareness instead of measuring it. These experiments compared participants who received explicit instructions about the

stimulus-probe associations to participants who did not receive these instructions. Consistently, it has been found that ABM with explicit instructions lead to greater initial learning during training. However, for those who are explicitly aware of the contingency, the change in attention bias did not result in a reduction in emotional reactivity to the subsequent stressor (Grafton et al., 2014; Lazarov et al., 2017).

Overall, our findings suggest that contingency awareness may be necessary for contingency learning or that contingency learning is more likely for those that show evidence of contingency awareness. The association between contingency awareness and attention bias acquisition supports a strong single-process model of learning (Lovibond & Shanks, 2002). The possibility that attention bias training is not based on intuitive and automatic responses, as has previously been suggested (Bar-Haim et al., 2007; Beck, Emery, & Greenberg, 2005; Eysenck et al., 2007; Koster et al., 2009; Williams et al., 1988). Higher cognitive processes, like contingency awareness seem to be important as well, which is recognised by many other models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). Solely relying on concepts of automaticity is insufficient to explain attention bias training in most situations. A comprehensive theory of attention bias and attention bias change calls for an understanding of the interaction of cognitive with automatic processes.

### **The Effect of Individual Differences in Attention Control on Attention Bias Modification**

Attention bias was not acquired as a result of exposure to a stimulus-probe association and levels of anxiety neither explained any variance in attention bias or attention bias trainability. Therefore, other possible moderators of attention bias acquisition were assessed in Experiment 5. These were attentional control of selectivity and attentional control of inhibition. The attention control task of Basanovic et al. (2017) was employed after ABM and a significant association between attention control of inhibition and attention bias measured within the training phase was found. Those with higher control of inhibition showed an attention bias towards the congruent stimuli in training. It seems that attention control of inhibition and not selectivity is an important predictor of attention bias acquisition. This is partially in line with previous research (Basanovic et al., 2017; Everaert et al., 2017). Basanovic et al. (2017) used an identical attentional control assessment task and found a significant association between attentional control of

inhibition and attention bias change. Unlike the findings in Experiment 5, Basanovic et al. (2017) also found a marginally significant association between attentional control of selectivity and attention bias change. Everaert et al. (2017) measured cognitive control of inhibition, shifting and updating. They found that inhibitory control was associated with attention bias change. This suggests that attentional control of inhibition has more influence on attention bias malleability as opposed to attentional control of selectivity.

### **The Reliability of the Dot-Probe Task**

The reliability of the dot-probe task has been discussed as a problem of the ABM paradigm. Recently, MacLeod et al. (2019) stated that there are two aspects to the reliability problem. First, studies have treated the reliability problem as if individuals may not show stable patterns of attentional responding to threat (e.g., Zvielli et al., 2015). Second, existing attentional bias assessment tasks may not satisfy the psychometric requirements that an assessment instrument must fulfil to adequately classify individuals (McNally, 2018; Rodebaugh et al., 2016). The mean-split half and Spearman-Brown reliability of the dot-probe assessment task was assessed in each condition and assessment phase in which a 50% contingency was employed in all five experiments of the first study. The congruent vs the incongruent trials were compared randomly over 5000 iterations. The findings can address both aspects of the reliability problem, which will be outlined below.

Overall, the split-half and the Spearman-Brown reliability scores were statistically not different from zero or unacceptably poor (between 0.24 and 0.53) in all assessment phases across the five experiments. According to the first aspect of the reliability problem, attention bias may not be a stable construct. This was also evident in the results of Study 1 as some training phases were successful in inducing an attention bias, while the assessment phases after these training phases were not able to capture the bias acquired in training. This suggest that attention bias is not stable and dependent on contingencies employed by the dot-probe task. According to the second aspect of the reliability problem, the dot-probe assessment task needs to adequately classify individuals into either having or not having an attention bias. The findings of the five experiments indicated the inefficacy of the dot-probe assessment task. The assessment phases across the experiments were not able to detect an attention bias towards the congruent or emotional stimuli compared to the incongruent or neutral stimuli, either in everyone or in those high in anxiety versus

those low in anxiety. This suggests that the dot-probe assessment task used in Study 1 was not adequate in reliably assessing the existence or the lack of, attention bias to non-emotional stimuli in Study 1 – Experiments 1 to 3 or to emotional stimuli in Study 1 – Experiments 4 and 5.

Kruijt and Carlbring (2018) proposed that future studies should focus on the question of whether the dot-probe task can reliably modify bias for individuals with a consistent and high pre-existent bias. However, it is first necessary to establish how the dot-probe task can reliably assess a consistent and high pre-existing bias. Therefore, other methods of measuring a reliable attention bias need to be considered, as successfully done by MacLeod and Grafton (2017) with their double probes in the dot-probe task. Furthermore, according to MacLeod et al. (2019) further research is also recommended to assess whether compound scores of multiple existing assessments of different attention bias measures (i.e., EEG and dot-probe task) or multiple assessments of the dot-probe assessment task may increase the reliability of the attention bias assessment.

### **Limitations of Study One and Recommendations for Future Research**

#### **Lack of Attention Paid to the Stimulus**

The main concern of Study 1 involves the participants' lack of attention towards the stimuli, either automatic (driven by the emotional content) or volitional (driven by the stimulus-probe association in training). It seems that most participants only attended to the probe and ignored the stimuli that preceded the probe. This is problematic since the dot-probe task measures attention bias through assessing the differential responding to probes that were presented in the same location as an emotional versus a neutral or a congruent versus an incongruent stimulus. Attention bias cannot be assessed with the dot-probe task when the participant ignores the stimuli presented before the probe. Future research could address this concern by making the stimulus-probe association task relevant. For instance, the dot-probe task could be modified such that participants need to remember a certain aspect of the stimuli to provide a response to the probe. Participants would then need to respond whether the task relevant aspect was evident in the stimulus presented in the same location as the probe. This would ensure that participants pay attention to the probe.

### **Lack of Transfer between Training and Assessment Phases**

Attention bias change was only found in the within-training assessment in one of the two training phases and not in the post-assessment phase. The use of the 95% contingency within the training phase allowed us to assess evidence of attention bias acquisition and change, while participants were receiving active attentional training. Previous studies unsuccessful in ABM, which used 100% contingencies in the ABM training (e.g., Naim, Kivity, Bar-Haim, & Huppert, 2018), cannot establish whether the lack of a bias change is due to unsuccessful training or due to unsuccessful transfer of the attention bias to the post-training assessment. Further studies ought to include a within-training assessment to disentangle these two possible reasons for failure related to attention bias change. Furthermore, it may be appropriate for future ABM studies to include assessment within the ABM training contingencies to permit assessment of attention bias, and reduce the likelihood of subsequent bias extinction. The assessment within-training seems to be more sensitive in measuring an attention bias as opposed to a post-training assessment. In turn, the reliability of attention bias assessment and training may increase.

It may be advisable to develop different post-assessment procedures where, for instance, subtle changes to the contingencies are introduced, rather than an abrupt change. According to the exploration-exploitation decision making hypothesis (Daw et al., 2006; Laureiro-Martínez et al., 2015), when the contingency radically changes, the context will also change radically from training to assessment phase. Participants who were using the contingency to enhance their task performance may then relinquish that strategy in favour of another to maximise performance on the task. Instead, if the context gradually changes by incrementally altering the contingency, participants may be less likely to alter the strategy used in the training phase. Consequently, a more gradual shift in contingency may be less likely to disrupt an acquired pattern of bias, and, therefore, an attention bias can also be evident in the post-training assessment phase. Future research could investigate how attention bias change can be assessed without the influence of a discrete assessment phase on the attention bias patterns acquired during training. In addition to changing the contingency more subtly, attention bias can possibly be measured in a more direct way, overcoming the need for any change in contingencies. For instance, a free viewing task could be employed that measures eye-gaze as suggested by Armstrong

and Olatunji (2012). It is important to investigate other ways of attention bias assessment that do not include an abrupt stimulus-probe contingency change. The findings of Study 1 revealed that a change from predictive to a non-predictive contingency resulted in attention bias extinction. The methods suggested above may eliminate the possibility of attention bias extinction and, thus, increase the reliability of attention bias assessment.

### **Limited Assessment of Contingency Awareness**

A limitation of the experimental design was that awareness of the stimulus-probe associations employed in the dot-probe task was assessed with a self-report at the end of the experiment. In accordance with the recommendations of Lovibond and Shanks (2002) the measure of awareness was relevant, sensitive, and not reactive. That is, the measure was relevant as it asked about the stimulus-probe contingencies directly related to the stimulus-probe associations in the dot-probe task. The measure was sensitive because it included a free recall as well as a recognition test to assess awareness. Lastly, the measure was not reactive because awareness was assessed after the dot-probe task, thus, the assessment did not influence further responding by directing attention to the stimulus-probe association. Nevertheless, the recommendation of immediacy was not met since the awareness was assessed at the end of the experiment, after multiple stimulus-probe contingency changes. This has its limitations, such that participants may have had difficulties with remembering or reporting the contingencies. Nonetheless, these difficulties were taken into account by not classifying participants according to the correctly reported contingencies. Participants were categorised as aware when they reported (on multiple-choice items) that any contingency was present, regardless of whether it was the correct contingency, while participants were categorised as not aware when they reported no awareness of any contingencies having been present. Furthermore, at the time of the study's design, immediacy was chosen to be sacrificed (i.e., awareness was assessed post-ABM), since the recommendation of reactivity (i.e., awareness assessment influencing ABM) was found to be more important.

Previous research has measured contingency by manipulating contingency awareness via explicitly telling participants about the contingency (Grafton et al., 2014; Lazarov et al., 2017). This method may be limited as well, as it is possible that participants who were not told about the contingency, but who acquired awareness

confounded the between-group effect by themselves. While Grafton et al. (2014) assessed contingency awareness with a self-report at the end of the procedure; the authors only disclosed that 73% of those in the explicit ABM also reported to be aware of the contingency. The authors did not state the proportion of participants who reported to be aware in the non-explicit ABM condition. Moreover, in their first experiment, the proportion of participants who became aware of the contingency without instructions was 21.9%. This proportion is similar to that in Study 1, which showed that at least one-third to half of all participants acquired awareness without explicitly being told about the stimulus-probe contingency. It is suggested that studies that compare different instruction types should control for the possibility that participants can acquire contingency awareness without the explicit instruction.

Contingency awareness should be measured with an immediate measure that does not influence the responding in the dot-probe task. Recently, Arad et al. (2018) measured contingency awareness with EEG and used the mismatch negativity ERP as an indicator of contingency awareness. Mismatch negativity has been associated with violations of statistical contingencies (Arad et al., 2018). Participants in their experiment completed a dot-probe training task with an 80% congruency. They found that the visual mismatch negativity ERP was a clear indication of contingency awareness during ABM. Furthermore, the amplitude of the mismatched negativity ERP predicted improvement in clinically assessed and self-reported social anxiety symptoms after ABM. This is a promising method of measuring contingency awareness without interfering with the ABM training. Furthermore, this method seems to be sensitive and relevant, therefore, adhering to all the recommendations made by Lovibond and Shanks (2002). Another way to assess contingency awareness while completing ABM may be by using online expectancy rating trials. For instance, test trials can be provided intermittently during the dot-probe training task where, for instance, question marks will appear instead of a probe. The participants are then required to predict the location in which the next probe will appear. An additional advantage of these immediate measures lies in the ability to assess time-related contingency awareness effects, in other words, the degree to which the contingency is acquired over time. This provides additional information clarifying whether contingency awareness precedes or succeeds contingency learning.

As stated before, approximately one-third to half of all participants consistently acquired awareness. Individual differences shown to be important in

other contingency learning tasks include low arousal and greater cognitive processing, like better working memory (Cosand et al., 2008) or greater attentional focus (Hur, Jordan, Berenbaum, & Dolcos, 2016). It may be that those concepts are related to the ability to acquire awareness of contingencies in the dot-probe task. Support for individual differences in acquiring awareness was provided in Chapter 4. There were significant differences in state and trait anxiety between those aware and not aware of the contingency. It seems that individuals low in state and trait anxiety were more likely to become aware of the stimulus-probe contingency than those with higher levels of anxiety. This suggests that high levels of anxiety possibly interfere with acquiring contingency awareness. However, this difference was not associated with different attention bias patterns at baseline or in any subsequent phases. Furthermore, the acquisition of contingency awareness was related to attentional control of selectivity (not to attentional control of inhibition). The results showed that those aware of the stimulus-probe contingency had a marginally higher cost of attentional selectivity than those who reported not to be aware of the contingency. This suggests, contrary to the hypothesis, that lower attentional control is associated with acquiring contingency awareness. However, given that this effect was only marginally significant, it has to be interpreted with caution. Therefore, another recommendation for future research is to investigate why some individuals acquire awareness without explicitly being told, while others do not. It is recommended that further research investigates other individual differences in acquiring awareness of the contingency as these may explain why some individuals become aware of the stimulus-probe associations used in the dot-probe task, while others do not. Especially, because the change in selective attention can lead to a change in psychopathology and the results of the first three experiments in Study 1 showed that selective attention was only changed in individuals aware of the contingency.

#### **Limited Evidence to Establish the Role of Attention Control in Attention Bias Modification**

The results of Experiment 5 indicated that attention control of inhibition was strongly and positively associated with attention bias acquisition in ABM training to neutral stimuli, away from threat. In contrast to the current findings, previous studies found that attentional control was associated with attention bias change measured from pre- to post-training, irrespective of the training direction (Basanovic et al.,

2017; Everaert et al., 2017). The findings of Experiment 5 showed that attentional inhibitory control was only associated within the attention training away from emotional stimuli. The difference between the design of Experiment 5 and previous research is related to the procedure where attention control was measured post-ABM, instead of pre-ABM. This difference in design may explain why the training direction was relevant for the association between attention control of inhibition and attention bias change in Experiment 5. As attention control was measured after ABM, it is possible that the ABM training changed attention control of inhibition, compared to attention control being measured pre-ABM. This is particularly true for participants in the ‘attend-neutral’ condition, as they are trained to attend to neutral stimuli and have to inhibit the more salient emotional stimuli. Chen et al. (2015) tested whether ABM increases attentional control assessed with an anti-saccade task using an eye-tracker. They found that attention control of inhibition increased from pre- to post-ABM compared to placebo training. Participants in the ABM condition received a 100% congruency training to attend to neutral stimuli. This finding supports the idea that the association between attentional control of inhibition and attention bias acquisition in the ‘attend-neutral’ training condition, found in Experiment 5, may be causal. That is, the ‘attend-neutral’ training direction in ABM increases attentional control of inhibition. It would be interesting for further research to test this causal hypothesis by testing attentional control of inhibition pre- and post-ABM (including both training directions) versus placebo training. This may be done either with the ACA task used in Experiment 5 of the current research project or with the anti-saccade task employed by Chen et al. (2015) using the eye-tracker. Such an experiment will establish whether attention control is an individual trait or state, and whether the direction of the ABM training influences change in attentional control.

### **Review of Research Findings in Study Two: Attentional Processes Responsible for Attention Bias Change**

The second study investigated how attention bias change influences attentional engagement and disengagement processes when employing different training procedures in the ABM paradigm. In particular, the existence of an attentional engagement and disengagement bias were assessed pre- and post-ABM training with the attentional process assessment (APA) task (Grafton & MacLeod, 2014; Rudaizky et al., 2014). One experiment was conducted wherein the conventional dot-probe training task was compared to a new gamified ABM training

task (the emotion-in-motion task). This was done to explore several non-mutually exclusive hypotheses, which examined whether the two different ABM training tasks would change one or both of the attentional processes thought to affect performance in the original dot-probe task, in addition to ascertaining whether the two different training tasks changed the same or different processes.

The findings supported the first hypothesis: changes in biased attentional disengagement were responsible for ABM induced changes in attentional bias. The results indicated a main effect for attention bias type, such that all participants showed an overall disengagement bias. Moreover, this effect interacted with the measurement time (pre- to post-ABM), however, not with training direction ('attend-neutral or 'attend-angry') or condition (dot-probe task vs emotion-in-motion task). Furthermore, the data did not support the second or third hypotheses, which stated that changes in biased attentional engagement alone (H2) or that both processes (H3) were responsible for ABM induced changes in attentional bias. There was no evidence to support the existence of an engagement bias with angry faces at baseline or after training.

### **Single versus Dual Attention Bias Account in Attention Bias**

In the general introduction it was discussed whether a single or a dual account could best explain attention bias towards threat. The single biased attentional process account holds that only the attentional engagement or only the attentional disengagement process is responsible for attention bias to threat in individuals with high levels of anxiety. Some researchers found that only the attentional engagement to threat process was enhanced in those with an attention bias to threat (Koster, Crombez, Van Damme, et al., 2004; Koster et al., 2006; Salemink et al., 2007), supporting a *single biased attentional engagement account*. Whereas other researchers found that only the attentional disengagement from threat process was impaired in high anxious individuals (Fox et al., 2002; Yiend & Mathews, 2001), supporting a *single biased attentional disengagement account*. The *dual biased attentional process account* was proposed by Rudaizky et al. (2014) and Grafton and MacLeod (2014) who tested the APA task and found that both the attentional processes of engagement and disengagement to threat were independently biased in those high in anxiety.

Study 2 tested the attentional processes with the APA task, which adheres to the three criteria of Clarke et al. (2013). These criteria significantly improve the ability of the assessment task to disentangle engagement and disengagement processes compared to the previously used assessment tasks. However, in contrast to Grafton and MacLeod (2014) and Rudaizky et al. (2014), the results of Study 2 did not find strong support for the dual biased process account. Overall, only the disengagement process was found to be biased in all participants, supporting a *single biased attentional disengagement account*. Nevertheless, there was a marginally trending 4-way interaction, which revealed that those trained to attend to neutral faces in the dot-probe task changed from enhanced engagement with neutral faces at baseline to no engagement bias post-training. Conversely, participants who completed an attention training to angry faces with the dot-probe task changed from no disengagement bias at baseline to an enhanced disengagement bias from angry faces post-training. These attention bias changes were indexed by a marginally trending interaction and are likely to represent a random effect (i.e., regression to the mean) as only one of the two pair-wise comparisons was in the same direction as the training provided. Moreover, the engagement bias found with neutral faces at baseline in one condition of the dot-probe task was unexpected given that attention and emotion theories, described in Chapter 1, theorise that emotional stimuli capture attention more rapidly than neutral stimuli.

#### **Attention Bias Change with the Dot-Probe Task and Emotion-in-Motion Task**

The fourth hypothesis, which explored whether the dot-probe task and the emotion-in-motion task induced the same or different change in biased attentional processes, was supported. There was a significant interaction between time of measurement and ABM training task, which showed that those trained with the dot-probe task achieved a significant bias change from pre- to post-training, whereas those trained with the emotion-in-motion task did not. This is in contrast to the findings of Notebaert et al. (2018), who found that the emotion-in-motion task was successful in acquiring an attention bias change. The bias change scores observed in their study indicated a small 2.7% improved in the tracking of happy faces compared to angry faces pre- to post- ‘attend happy’ training. Since the significant effect in Notebaert et al. (2018) was found in the ‘attend-happy’ training condition, our non-significant results may have been caused by the use of different training directions

(‘attend-neutral’ and ‘attend-angry’). Furthermore, in Notebaert et al. (2018), the significant bias change was assessed with an assessment version of the emotion-in-motion task. The non-significant findings observed in our experiment may be due to the lack of far transfer to a different assessment task.

An alternative possibility is that the game elements in the emotion-in-motion task may have distracted attention away from the learning that underlies successful attention bias change as suggested by Forman et al. (2018). The continuously moving and changing faces in the emotion-in-motion task may have disrupted participants’ acquisition of attention bias. The previous experiments in Study 1 showed that attention bias change was not easily accomplished. This implies that training of selective attention is not as straight forwards as initially thought. It seems that merely directing selective attention continuously to certain stimuli may not lead to an attention bias change. Multiple factors seem to influence stimulus-probe associative learning. Given that these difficulties in learning were evident in a controlled experiment, with non-emotional stimuli, the additional gamification elements may bring in even more additional factors that can interfere with learning. It is encouraged that future research first investigates how to achieve a reliable attention bias change, before altering the training task to achieve a potentially not outcome related effect such as making it more enjoyable to complete.

The results showed that the attention bias change pre-to post-ABM with the dot-probe task was only evident in the attentional disengagement bias scores. Furthermore, they revealed that the dot-probe training task trained participants to remain focused on the angry faces, irrespective of the direction of training. It is a challenge to explain why two differently directed stimulus-probe contingencies that are assumed to underlie learning of attention bias would result in an attention bias in the same direction. It is possible that not only bottom-up contingency learning, but also other higher-order processes underlie attention bias change as well. These processes include attention control and contingency awareness.

### **Limitations of Study Two and Recommendations for Future Research**

The current study altered the APA tasks from an IAPS into a face version and the training direction in the emotion-in-motion task from ‘attend-happy’ to ‘attend-neutral’. These changes in stimuli and training conditions could have influenced the results. Therefore, further studies are encouraged to replicate this experiment using stimuli from the IAPS database and assess attentional engagement and

disengagement bias pre- and post-different ABM training tasks and conditions (attend-happy, -neutral and -angry or -disgust). Furthermore, the attentional disengagement bias changed pre- to post-ABM training with the dot-probe task, however, for participants in both training directions. This suggests that higher order processes may play a role in the change of disengagement biases. Given that Experiment 5 in Study 1 showed that attentional control of inhibition might be changed through ABM, it would be interesting to investigate whether this change is mitigated by the change in attentional disengagement bias. In particular because inhibiting and disengaging from stimuli seems to be related (Taylor et al., 2016). Therefore, future research is encouraged to assess attention control and attention processes pre- and post-ABM and analyse whether a change in attention control is associated with a change in attentional disengagement biased process.

The limitations of Study 2 include the existence of a pre-group difference in attentional engagement and disengagement. The results showed that participants in the 'attend-neutral' condition were the only ones who had an engagement bias towards neutral faces and a disengagement bias with angry faces at baseline. Participants in the other conditions revealed no attentional bias at baseline. Hence, it is recommended that this study is replicated in a sample that has equivalent processes of attention bias at start. This may be achieved by pre-selecting participants with equal levels of anxiety, as it is more likely that a homogenous sample will show similar processes of attention bias.

### **Theoretical Implications**

The two studies presented in this research project showed that the direction of selective attention towards a certain stimulus category by providing a predictive stimulus-probe association does not automatically result in attention bias acquisition or change. This implies that attention bias training is unlikely to only be based on intuitive and automatic responses as previously suggested (Bar-Haim et al., 2007; Beck et al., 2005; Eysenck et al., 2007; Koster et al., 2009; Williams et al., 1988). Higher cognitive processes, like contingency awareness and attention control, seem to be important as well, as is recognised by many other models (Beck & Clark, 1997; Lovibond & Shanks, 2002; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998).

The importance of top-down processes, like awareness and attentional control, have been evidenced in studies that investigated attention in patients with lesions in the right cerebral hemisphere, which results in *visuospatial neglect*. In this

condition, visual sensation (i.e., bottom-up processing) is intact, however, patients fail to detect or become aware of stimuli in the side of space opposite of the lesion (Mesulam, 1981; Rafal, Ward, & Danziger, 2006). Other studies have shown that lesions in other parts of the brain, including the parietal lobe, frontal lobe, anterior cingulate cortex, basal ganglia, and the thalamus also resulted in visuospatial neglect (see for review: Pessoa et al., 2002). This evidence has led to the notion that stimuli from the environment are processed top-down through a distributed network and not only through visual bottom-up processes. Therefore, solely providing bottom-up stimulus-probe associations may not be sufficient to modify attention bias. Other top-down approaches need to be considered as well, such as increasing the acquisition of contingency awareness. Before we consider theory building, research that investigates new ways of modifying attention bias are needed. Especially studies that test the efficacy of ABM using top-down and bottom-up approaches.

A modified ABM training task that enhances top-down learning of a stimulus-probe contingency could include specific learning trials presented among the traditional dot-probe trials that resemble a classical fear conditioning paradigm (Luck & Lipp, 2016). In such learning trials, neutral stimuli (i.e., neutral faces) could be paired with a positive stimulus (i.e., pleasant picture or sound) and negative stimuli (i.e., angry faces) could be presented alone. By doing this, participants may learn to attend to the safe stimuli and ignore or suppress the threat stimuli in subsequent trials where both stimuli are presented. The additional learning trials may facilitate top-down attention to the stimuli that precede the probes, which in turn enhances learning of the stimulus-probe contingency. In addition, participants in classical conditioning paradigms are often aware of the pairings (Reiss, 1980). The awareness of such learning trials may transfer to the stimulus-probe pairings of the dot-probe trials resulting in better training of selective attention. Future research is required to test whether augmentation of the attention bias modification paradigm with additional contingencies can create a new ABM task that would be more effective in changing attention bias and subsequently relieve psychopathology.

This research project was the first to investigate the most basic stimulus-probe associative mechanism responsible for attention bias assessment, change and acquisition with the dot-probe task. Additionally, it was the first to investigate how the processes of engagement and disengagement that underlie attention bias behave when different ABM training tasks are employed. The results of this research project

revealed that there seems to be a need to develop a theory or extend on existing theories to explain how attention bias can be changed. Existing theories of attention bias, described in Chapter 1, focus on how attention bias is acquired, not on how it is changed. The development of testable hypotheses which state how attention can be changed and what conditions are necessary to achieve this change would allow researchers to develop ABM training paradigms that are able to change attention bias more reliably. This research project contributed to the development of such a theory by showing that attention bias change is not easily replicated and is subject to several moderators. The difficulty of replicating attention bias change and the existence of possible hidden moderators is further supported by the mixed findings on this topic. The experiments in this research project found evidence of two individual differences that effect attention bias change, these were the levels of acquired contingency awareness and attentional control of inhibition. More research is required to replicate the findings in this thesis and future experiments are needed to build upon the recommendations made before existing theories can be extended or new theories developed.

In sum, the experiments presented in this thesis showed that the exclusive use of a bottom-up approach to change attention bias, whereby stimuli are associated with probes, seems to be insufficient to induce attention bias change in most situations. Therefore, developing a more specific theory that includes different pathways to attention bias change and predicts attention bias change combining bottom-up as well as top-down approaches is particularly important. Especially, since emotion vulnerability related to psychopathology can be reduced when attention bias change is successfully induced. Thus, it seems to be requisite that a theory integrates automatic as well as controlled processes involved in successful attention bias change. A complete understanding of how attention bias is changed will further aid the development of clinical interventions that can successfully target emotional dysfunction in a range of emotional and non-emotional disorders.

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