Trends in Cognitive Sciences

CellPress REVIEWS

Opinion

Anxiety and Threat-Related Attention: Cognitive-Motivational Framework and Treatment

Karin Mogg[1,2,*] and Brendan P. Bradley[1,2]

Research in experimental psychopathology and cognitive theories of anxiety highlight threat-related attention biases (ABs) and underpin the development of a computer-delivered treatment for anxiety disorders: attention-bias modification (ABM) training. Variable effects of ABM training on anxiety and ABs generate conflicting research recommendations, novel ABM training procedures, and theoretical controversy. This article summarises an updated cognitive-motivational framework, integrating proposals from cognitive models of anxiety and attention, as well as evidence of ABs. Interactions between motivational salience-driven and goal-directed influences on multiple cognitive processes (e.g., stimulus evaluation, inhibition, switching, orienting) underlie anxiety and the variable manifestations of ABs (orienting towards and away from threat; threat-distractor interference). This theoretical analysis also considers ABM training as cognitive skill training, describes a conceptual framework for evaluating/developing novel ABM training procedures, and complements network-based research on reciprocal anxiety–cognition relationships.

Search for Cognitive Mechanisms in Anxiety and New Treatments

Anxiety disorders are common mental-health problems that are burdensome for sufferers and health services [1]. Treatments include medication and cognitive behavioural therapy (CBT); however, many anxiety sufferers fail to respond, or relapse [1,2]. Consequently, there is need for additional treatment options which are effective, low-cost, and easily delivered. One potential computer-delivered treatment is attention-bias modification (ABM) training. ABM training arose from research in **experimental psychopathology** (see Glossary), and draws on theory and methods in experimental cognitive psychology to examine and modify attention processes in anxiety. The original version, ABM threat-avoidance training, is based on assumptions that anxious individuals have an enduring automatic tendency to attend preferentially to threat information [3], and reduction of this **attention bias** (AB) should reduce anxiety [4,5].

However, there is dispute about the clinical effectiveness of ABM training and the cognitive processes underlying anxiety and threat-related ABs. The purpose of this article is several-fold: to provide a brief overview of these issues, which builds on and extends our previous reviews [6,7]; to describe an updated cognitive-motivational model of anxiety and threat-related attention; to view ABM training as cognitive skill training; to apply the distinction between processes and procedures [8] to this updated perspective; to describe a conceptual framework for evaluating and developing novel ABM training procedures; and to encourage network-based research evaluating reciprocal anxiety–cognition relationships.

Trends

Research in experimental psychopathology has led to the development of ABM training as a potential computer-delivered treatment for anxiety disorders.

Conventional ABM threat-avoidance training encourages anxious individuals to orient attention away from threat, but has variable effects on anxiety and threat-related ABs.

Differing explanations for mixed outcomes of ABM training, and theoretical controversy about the causes of anxiety and ABs, encourage the development of alternative novel ABM training methods.

Development of effective attention-based treatments for anxiety would be advanced by better theoretical understanding of the cognitive processes underlying anxiety and ABs, and by using more refined and comprehensive assessments of threat-related attention and associated cognitive and neural functioning.

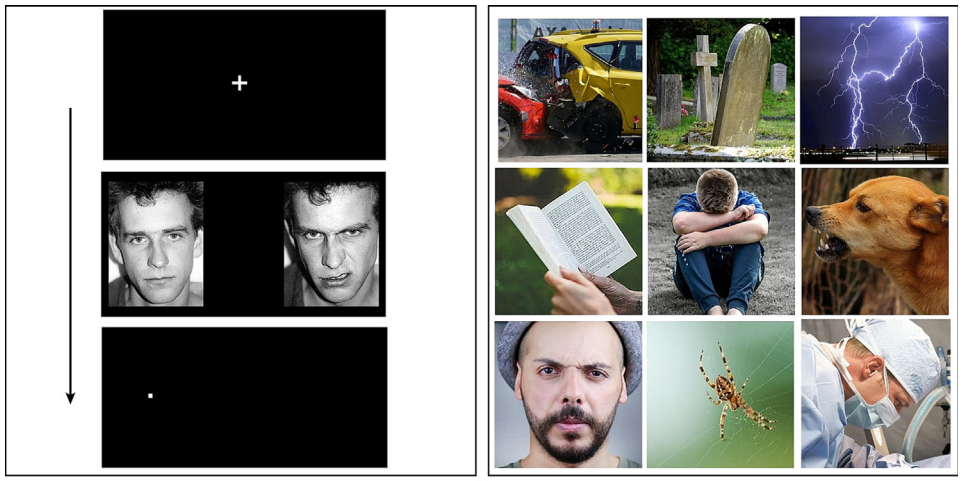
[1]Psychology, University of Southampton, Highfield, Southampton, SO17 1BJ, UK
[2]Hughes Hall, Cambridge, CB1 2EW, UK

*Correspondence: kmogg@soton.ac.uk (K. Mogg).

Turning Point in ABM Training Research

The most widely used method, ABM threat-avoidance training, typically employs a modified **visual probe task** to train anxious individuals to direct attention away from threat [4]. Each trial presents a threat and nonthreat cue simultaneously in different locations of a computer screen, immediately followed by a probe (e.g., a dot) which replaces one of the cues (Figure 1). Participants respond as quickly as possible to the probe. In ABM threat-avoidance training, probes are unlikely to appear in locations just vacated by threat cues. Hence, training (many hundreds of trials) encourages **orienting** of attention away from the location of threat.

Since its introduction about 15 years ago, over 30 studies have evaluated the effects of ABM threat-avoidance training on anxiety symptoms and AB in high-anxiety individuals. Despite initial promising results, many studies report disappointing outcomes [6–16]. ABM threat-avoidance training is often no more effective in reducing anxiety than control attention training (e.g., a visual probe task in which probes are equally likely to replace threat and nonthreat cues) which combines attention task practice and threat-cue exposure, but does not encourage threat-avoidant orienting. Recent reviews and meta-analyses conclude that conventional ABM threat-avoidance training has inconsistent effects on anxiety and AB [6–16], and is therefore



Trends in Cognitive Sciences

Figure 1. Illustration of Visual Probe and Visual Search Tasks Used in Attention-Bias Modification (ABM) Training. (Left panel) Example of a trial on the visual probe task used in conventional ABM threat-avoidance training. Following a central fixation cross, a threat and nonthreat cue (e.g., angry–neutral face-pair, illustrated; or threat–nonthreat word-pair) appear together, typically for 500 ms, for example, [4,80,81,83–87]. Threat cue location varies randomly across trials. A probe then appears in the location of either cue. Participants are instructed to respond to the probe by pressing a response button as quickly as possible. Probes may be dots (illustrated; 'dot probe task'), letters, or arrows. In ABM threat-avoidance training, probes rarely appear in the location of threat cues to encourage participants to orient away from threat. In control attention training (a comparison condition commonly used in ABM threat-avoidance training studies), and in the assessment version of the visual probe task (used to measure attention bias, AB), the probe is equally likely to replace threat or nonthreat cues. In the assessment version, AB is inferred from probe response times: faster responses to probes replacing threat than nonthreat cues indicate AB in orienting towards threat, whereas slower responses to probes replacing threat than nonthreat cues indicate threat-avoidant AB. (Right panel) Example of a picture array in enhanced positive search training [75,76]. Each array (9 or 16 pictures) contains one or two nonthreat pictures (targets) embedded among negative and threat-related pictures (distractors). Nonthreat targets include positive pictures (e.g., children playing) and neutral/calm pictures (e.g., person reading book; illustrated). Participants are told to 'look for good', 'look for calm', or both, and respond by mouse-clicking on the corresponding pictures. The location and content of nonthreat target and threat-distractor cues vary randomly across trials (>350 different pictures). For copyright considerations, pictures are illustrative.

Glossary

Alerting: a noradrenaline-based attention system which produces and maintains a state of readiness to respond to incoming stimuli. Alerting is distinct from other key attention functions (attention control, orienting).

Attention bias (AB): the preferential tendency to allocate attention towards (or away from) stimuli which are motivationally/emotionally salient for the individual. It occurs in various psychopathologies; for example, ABs to threat cues in anxiety, negative information in depression, food cues in overeating, drug cues in addiction.

Attention control: ability to effortfully control attention to support tasks and goals. Component processes include goal-directed inhibitory attention control (also known as inhibition), flexible switching, and controlled attention-orienting, which also contribute to the broader construct of cognitive control.

Cognitive control: involves multiple processes supporting goal-directed thought and action (also known as executive control). It includes attention control functions (goal-directed inhibitory attention control, flexible switching, controlled orienting), as well as reason-based evaluation/appraisal, and updating and maintaining information in working memory.

Emotional Stroop task: a widely used AB index of threat-distractor interference. Participants name the colours of emotional and neutral words printed in different colours, while ignoring their meaning. Threat-distractor interference is indexed by slower colour-naming of threat than nonthreat words.

Evaluation: of the significance and meaning of stimuli. It can take place automatically, as in rapid automatic evaluation of motivational-salience of stimuli, or reflectively and deliberatively, as in more elaborate reason-based appraisal of stimulus meaning and goal relevance.

Experimental psychopathology: uses objective laboratory-based methods to investigate mechanisms causing and maintaining psychological disorders. It draws on multiple disciplines including experimental psychology,

unsuitable as a treatment for anxiety. Other ABM training methods (considered later) may be more effective, but outcome data are preliminary.

Hence, ABM training research is at a turning point, with diverse recommendations: (i) research into ABM training as a treatment for anxiety should be abandoned [9]. (ii) ABM training procedures should be improved to be more effective in training threat-avoidant attention-orienting [5,8,17]. (iii) The theoretical premise of ABM training should be reconsidered, and ABM training methods revised to target multiple processes underlying anxiety and ABs [6,7,18,19]. This article considers evidence-based cognitive perspectives of anxiety, threat-related attention, and cognitive skill training which may guide future research.

Why Does Conventional ABM Training Have Unreliable Anxiety-Reducing Effects?

To improve the efficacy of ABM training, it is helpful to consider why conventional ABM threat-avoidance training does not consistently reduce anxiety as expected. An important distinction is between target processes and training procedures [8].

Poor outcomes may be explained by deficient training procedures: if ABM threat-avoidance training fails to modify its target process (i.e., reduce pre-existing AB in orienting towards threat), this could explain its failure to reduce anxiety [5,8,16,17]. For example, ABM threat-avoidance training is less effective when delivered at home than in laboratory/clinic settings, possibly because greater distractions at home impair learning [8,13]. ABM threat-avoidance training is also repetitious and boring, which may reduce treatment compliance [20,21]. The implication would be to improve ABM threat-avoidance training procedures, for example by reducing distraction and by making training more engaging [8,20,21].

Another explanation for poor outcomes concerns the target process: if AB in orienting towards threat does not play a strong causal role in anxiety, this may explain the inconsistent effects of ABM threat-avoidance training [6,11,12,18]. Other cognitive processes may underpin both anxiety and ABs to threat. If so, training procedures should be modified to target them.

Cognitive Processes Underlying Anxiety, Threat-Related ABs, and ABM Training

Numerous cognitive models of anxiety and threat-related ABs have emerged in the past 30 years (e.g., [3,6,22–32]; reviewed in [6]). We focus here on two perspectives with differing implications for ABM training: one perspective proposes that anxiety is caused by automatic AB towards threat, which can be targeted by conventional ABM threat-avoidance training; the other proposes that anxiety and ABs are caused by multiple cognitive processes, which can be targeted more effectively by multicomponent ABM training procedures.

AB Towards Threat as a Key Process Causing Anxiety

According to early cognitive views of anxiety, high-anxiety individuals have an enduring AB towards threat, whereas low-anxiety individuals are threat-avoidant [3]. AB towards threat is conceptualised as a stable trait-like characteristic which plays a causal role in anxiety; hence, interventions that reduce AB to threat should reduce anxiety [5,33]. Empirical research indicates that anxiety-related AB towards threat can operate automatically, outside awareness [6,25,34,35]. Thus, conventional ABM threat-avoidance training uses implicit training procedures (i.e., training without awareness of what is being taught) and relies on repeated practice

psychopharmacology, and cognitive neuroscience.

Inhibition: can be goal-directed or stimulus/salience-driven. Goal-directed inhibitory control refers to inhibition of processing task-irrelevant stimuli, and suppression of dominant responses, to support goal-relevant activity. Salience-driven inhibition refers to automatic interruption of ongoing cognitive/psychomotor activity, reflexively triggered by salient stimuli such as threat cues.

Network: comprises multiple interconnected components (nodes). Networks can interact and overlap with each other. They can represent cognitive, neural, or symptom variables.

Orienting: directing the focus of spatial attention, such as shifting between stimuli in different locations and maintaining focus on selected locations. Orienting can be automatically triggered by salient stimuli (salience-driven), or controlled (goal-directed).

Salience: stimulus salience varies along various dimensions including aversive (threat-related) and appetitive (reward-related) motivational salience, and perceptual salience (e.g., brightness, contrast). Motivational salience is influenced by stimulus content, individual differences, and situational variables (e.g., learning history, current motivational state, context).

Switching: can be goal-directed or stimulus/salience-driven. Goal-directed switching (also known as set-shifting) refers to flexible switching/shifting of attention priorities between tasks, mental sets, and goals (N.B., set-shifting is distinct from shifts in spatial attention-orienting). Automatic switching from goal-directed to salience-driven attention priorities can be reflexively triggered by salient stimuli.

Visual probe task: widely used to assess AB in attention-orienting towards or away from threat (Figure 1).

Working memory: a short-term memory buffer in which internal representations of goals and stimuli are maintained (e.g., by verbal rehearsal) and manipulated (e.g., by reasoning) to support goal-directed cognitive activity and behaviour.

on hundreds of trials to reduce automatic attention-orienting to threat (participants are typically not informed that the training goal is to induce threat avoidance) [5,33].

Cognitive-Motivational Framework of Processes Underlying Anxiety and ABs

Empirical evidence increasingly indicates that anxious individuals do not consistently exhibit AB towards threat, and sometimes show no AB or threat avoidance [6,12,18,25,31,36–39]. This may be explained by cognitive models of anxiety which propose that anxiety and ABs depend on multiple processes, including automatic **salience**-driven (also known as bottom-up, stimulus-driven) and goal-directed **cognitive control** (also known as top-down, executive control) processes [6,23–32]. These models have common themes which overlap with theories of attention and cognitive control [40–46]. These have been integrated within a cognitive-motivational framework, building on prior models of anxiety and attention, as well as on experimental evidence of anxiety-related ABs [6]. Accordingly, anxiety and threat-related ABs emerge from interactive salience-driven and goal-directed influences on multiple processes (Figure 2, Key Figure). The framework is updated here to highlight **evaluation**, **inhibition**, **switching**, and orienting functions within both salience-driven and goal-directed modes of processing, and distinguishes between salience-driven versus goal-directed switching.

Multiple cognitive functions support automatic salience evaluation/detection, which facilitates the rapid identification and response to threat cues in the environment (salience refers here to aversive-motivational salience). These include automatic salience evaluation, inhibition/interruption of ongoing activity, **alerting**, salience-driven switching, and reflexive orienting [40,43,47,48]. Salience evaluation is a core process that not only automatically evaluates the motivational importance of stimuli (threat value) but also modulates other processes to prioritise salient stimuli, for example by automatically triggering (i) inhibition/interruption of ongoing cognitive and psychomotor activity (also known as cognitive and behavioural freezing); (ii) alerting, which facilitates readiness to respond to incoming stimuli (e.g., in preparation for active defensive responses to threat); (iii) switching of priorities and resources of the cognitive system to salience-driven processing; (iv) orienting of spatial attention towards salient cues; and (v) enhancement of perceptual analyses of salient stimuli [40,43,47–50]. Anxiety may result from threat-hypersensitivity of the salience evaluation mechanism; in other words high-anxiety individuals evaluate mild threat cues as having high aversive-motivational salience (i.e., overestimate threat value), which contributes to subjective experience of danger (fear and anxiety), and abnormal attention responses to threat (described later). In addition, over-reactive threat salience-driven switching may cause excessive threat-prioritisation in cognitive system functioning (attention, **working memory**), and resultant anxiety [48].

Goal-directed cognitive control regulates thought and action according to current goals. It involves multiple processes, including goal-directed inhibitory control (also known as inhibition), flexible switching between tasks/goals, maintaining and updating goal-relevant information in working memory, reason-based evaluation/appraisal, and controlled orienting [26,40,42,45,46,51,52]. Goal-directed inhibitory control is a core function underlying **attention control**, and cognitive control processes generally [45], which operate in a coordinated manner to support goals [41,51]. Goal-directed inhibitory control is also important in emotion regulation by downregulating the reactivity of the automatic salience evaluation mechanism to threat cues [46].

Thus, multiple cognitive functions, organised as coordinated systems or **networks**, underpin salience-driven and goal-directed processing. Imbalance between these systems underlies emotion dysregulation, excessive anxiety, and threat-related ABs.

Key Figure

Cognitive-Motivational Framework of Processes Underlying Anxiety and Threat-Related Attention Biases (ABs)

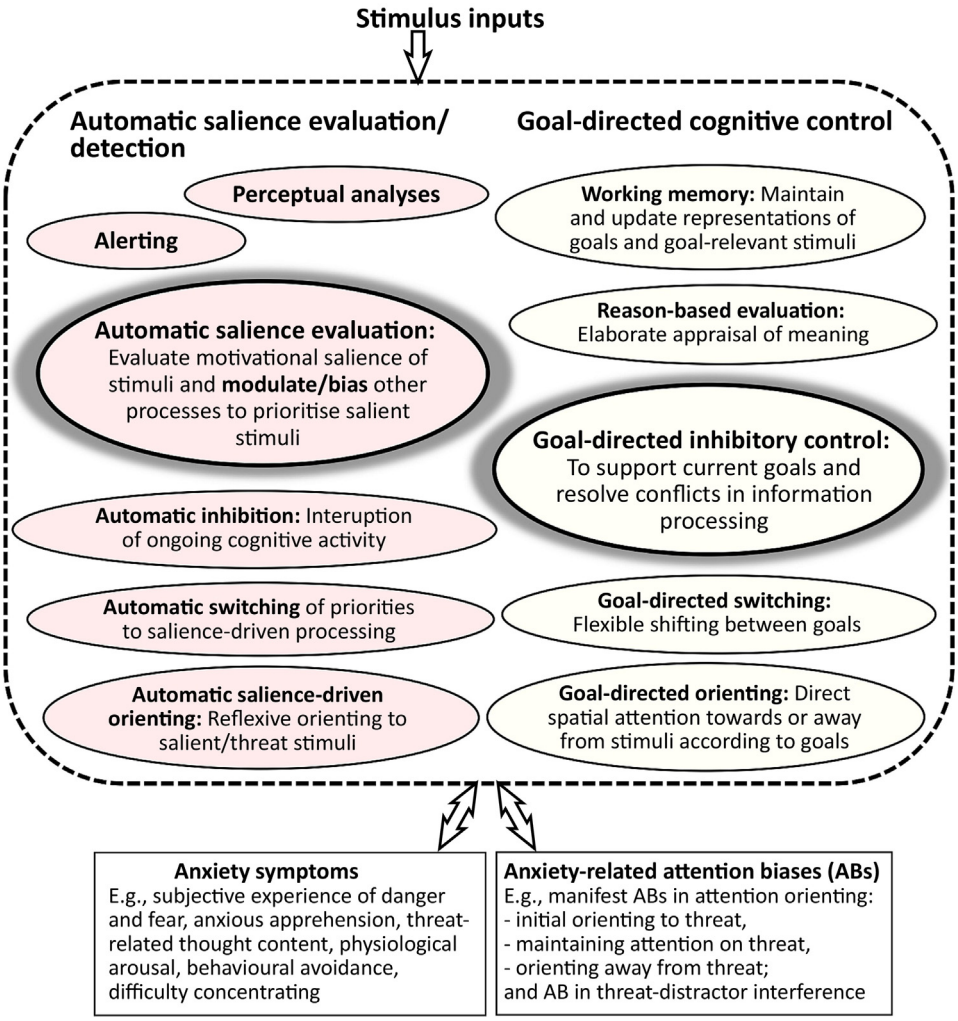


Figure 2. Multiple cognitive processes function in a coordinated manner to support automatic salience evaluation/ detection and goal-directed cognitive control (left and right sides of the Figure, respectively). Imbalance between threat salience-driven and goal-directed modes of processing underlies anxiety symptoms (e.g., subjective experience of danger, threat-related thoughts) and variable behavioural manifestations of anxiety-related ABs (initial orienting to threat, attention maintenance on threat, orienting away from threat, threat-distractor interference). In high-anxiety individuals, the automatic salience-evaluation mechanism is proposed to be over-reactive to threat cues and, when activated, influences other processes (e.g., inhibition, switching, orienting, alerting, perceptual analyses) to facilitate rapid identification and responding to threat. Over-reactivity of automatic threat salience evaluation, salience-driven switching, and orienting functions may each contribute to anxiety symptoms and ABs. In addition, goal-directed cognitive control functions may be ineffective or maladaptive in anxious individuals in regulating threat salience-driven processing, further contributing to and modifying threat-related ABs. The framework provides a rationale for interventions that encourage coordinated use of multiple goal-directed cognitive control functions (of which goal-directed inhibitory attention control is a key component) to

(Figure legend continued on the bottom of the next page.)

Salience-Driven and Goal-Directed Influences on ABs

Threat-related AB is often considered to be a unitary construct or process [5,12] which characterises anxious individuals. However, it is helpful to distinguish between differing AB indices and their underlying processes [25]. Empirical research indicates several manifestations of anxiety-related ABs, which are commonly uncorrelated [6,18,25,53]. ABs in attention-orienting are observed on spatial attention tasks (e.g., visual probe and eye-tracking tasks), and include initial orienting towards threat, maintaining attention on threat (also known as delayed disengagement), and orienting away from threat [6,25,29,53,54]. Another AB index is threat-distractor interference, reflecting impairment in task performance by task-irrelevant threat cues (e.g., slower colour-naming of threat than nonthreat words on the **emotional Stroop task**, which does not involve spatial orienting [55]). Meta-analytic findings indicate small-to-medium effect sizes of threat-related ABs in anxious individuals on visual probe and emotional Stroop tasks (d = 0.37–0.49 [28]). This may be explained not only by methodological problems in inferring ABs from response-time data but also by variation in ABs among anxious individuals, reflecting differing processes [11,19,25,36,56–58].

AB in threat-distractor interference (e.g., on the emotional Stroop task) reflects conflict between threat salience-driven and goal-directed processes [26,30,31,55,59]. Threat hypersensitivity of automatic salience evaluation and switching in anxiety may trigger inhibition/interruption of task-related activity, as well as switching of attention priorities from goal-directed processing to threat salience-driven processing (Figure 2), which impairs task performance; in addition, anxious individuals may vary in their capacity to inhibit salience-driven influences and maintain task-focused attention goals [26,27,30,31].

ABs in attention-orienting (e.g., on a visual probe task) may also reflect both salience-driven and goal-directed processes. These include reflexive orienting to stimuli triggered by automatic evaluation of aversive-motivational salience (i.e., motivational salience-driven) [29,34,35]. Anxious individuals may also strategically maintain spatial attention on threat cues to facilitate elaborate stimulus-appraisal and appropriate action (i.e., threat-monitoring goal) [25,54]. However, they may sometimes instead suppress AB to threat by effortfully focusing attention on task-relevant information (i.e., task-focused goal), particularly if they have good inhibitory attention control [27,60]. Further, some anxious individuals may strategically direct attention away from threat (avoidance) to reduce subjective distress (i.e., emotion-regulation/distress-reduction goal), particularly if they have high fear/trauma symptoms [25,29,36,37,39,53]. In sum, anxiety-related ABs likely reflect the current motivational/goal state of the individual (e.g., to detect, monitor, and/or avoid threat), that is in turn influenced by individual differences (e.g., anxiety/fear/trauma, attention control) and situational variables (e.g., threat duration/severity) ([6] for evidence). Hence, anxiety-related ABs vary between threat vigilance and avoidance [6,19,25,29,36].

Relationships between Anxiety, ABs, and Underlying Processes

AB in attention-orienting towards threat may not play a primary causal role in anxiety because anxious individuals sometimes exhibit threat avoidance or no AB [6,11,12,19,36–39]. Instead,

oppose automatic threat salience-driven influences on information processing, and support adaptive goal-directed attention; for example by explicitly prioritising processing of nonthreat information, such as positive/calm/neutral/task-relevant stimuli, over minor threat cues. Figure modified from Figure 4 of Mogg and Bradley 2016 [6] to highlight salience-driven and goal-directed influences on stimulus evaluation, inhibition, switching, and orienting functions. Each of these functions is now represented in both salience-driven and goal-directed modes of processing. Cognitive processes are closely interlinked (to simplify the figure, connections are not shown).

relationships between ABs and anxiety are probably reciprocal rather than being causally unidirectional [12]. Anxiety is commonly characterised by subjective experience of danger and fear, anxious thoughts, and physiological arousal. High anxiety may not only intensify threat salience evaluation (resulting in overestimation of stimulus threat value), but also impair goal-directed inhibitory attention control [26,52], both enhancing threat salience-driven ABs.

Conversely, ABs may influence anxiety [5,12,25,29,31,53,54]: automatic orienting to threat may increase detection of threat cues in the environment and awareness of potential danger, thereby enhancing anxious mood. Attention maintenance on threat and poor threat-distractor inhibition may exacerbate anxiety-related thoughts and worries. Threat-avoidant orienting may reduce immediate distress, but be maladaptive in the long term by impairing reason-based appraisal of feared stimuli, thereby impeding habituation and fear reduction.

Accordingly, anxiety and variable AB manifestations emerge from interacting cognitive-motivational influences on information processing, including threat-hypersensitive automatic salience evaluation, salience-driven switching and orienting, and inadequate/maladaptive goal-directed cognitive control. Reciprocal interrelationships between anxiety, ABs, and their underlying processes may maintain anxiety and be usefully modified by attention training procedures.

ABM Training as Cognitive Skill Training

ABM training may be viewed as cognitive skill training, whereby anxious individuals learn adaptive attention responses to minor threat cues (which are not objective dangers) to be applied in daily life. Research in cognitive skill training highlights the contributions of both explicit and implicit learning (i.e., learning with and without awareness/intention) [61,62], and identifies multiple training procedures which facilitate acquisition, retention, and transfer of cognitive skills. These include (i) explicit goal-setting, which helps individuals to direct attention to relevant stimuli and recruit effort to attain training goals; (ii) content-relevance of training, in other words a clear relationship between the content of the training task and everyday situations, which facilitates transfer; (iii) feedback, which helps individuals to regulate responses according to training goals; (iv) variation of training to reduce boredom and increase engagement (e.g., by varying stimuli and task demands, increasing task difficulty during training sessions); and (v) practice, which promotes automatisation [63–65].

Conventional ABM threat-avoidance training lacks most of these features because it relies primarily on repeated practice to reduce AB to threat, which is consistent with a widely held view of ABM training as an implicit training method of directly modifying automatic AB [16,33,66]. Thus, conceptualizing ABM training as cognitive skill training offers a different perspective. This predicts that learning to prioritise attention to goal-relevant nonthreat information, as well as to improve control over processing of irrelevant threat information, is facilitated by multiple procedures including explicit goal-directed training.

Implications for ABM Training Procedures

Distinguishing between target processes and training procedures [8] can guide the development of ABM training (Table 1). In conventional ABM threat-avoidance training, the target process is automatic orienting towards threat, and the training procedure is to repeatedly orient attention away from threat.

Table 1. Target Processes and Training Procedures Used in ABM Training Methods

Target processes		Training procedures (examples)
Salience evaluation/ detection	Automatic threat salience evaluation; including sensitivity to threat cues, and influence on other processes such as inhibition, switching, orienting	Exposure to threat cues
		Combination of multiple procedures to oppose automatic salience-driven influences on processing by promoting goal-directed cognitive control (see below) during threat cue exposure
	Automatic orienting to threat	Repeated orienting of attention away from location of threat cues
Goal-directed cognitive control	Coordinated recruitment of goal-directed cognitive control processes (to oppose salience-driven influences)	Explicit goal-setting; for example, specify goals of learning attention skills for prioritising nonthreat information (i.e., adaptive goal-directed ABs favouring positive/calm/neutral/task-relevant stimuli) and disregarding minor threats in everyday situations
	Inhibitory control of threat distractors	Selectively attending and responding to nonthreat target cues, which are simultaneously presented with threat distractors
	Goal-directed orienting	Controlled orienting of attention towards nonthreat target cues, which are relevant to everyday goals/situations
	Maintenance of goals in working memory	Goal-rehearsal; for example, verbalising adaptive attention goals such as 'look for calm'
	Goal-directed switching	Flexible shifting between adaptive attention goals, for example, look for positive or neutral information, or both simultaneously
	Reason-based evaluation/appraisal	Identifying threat cues as goal-irrelevant (i.e., unimportant)
Cognitive skill learning	Explicit learning	Instructions on training goals and the relevance of the training procedures to goals and everyday situations; feedback on performance during training
	Implicit learning	Repeated practice of adaptive attention skills to promote habitual use (automatisation); feedback on performance during training
	Motivational engagement	Variation in training procedures to reduce boredom and fatigue; for example varied stimuli and increasing task difficulty during and across training sessions to promote positive challenge and effort

The cognitive-motivational framework predicts that ABM training can reduce both abnormal anxiety and ABs by targeting multiple processes; in particular, automatic threat-hypersensitive salience evaluation, which influences inhibitory, switching and orienting functions; and goal-directed cognitive control, which opposes automatic salience-driven influences, and which supports threat-distractor inhibition, controlled orienting, flexible goal-switching, and goal-

maintenance (Figure 2). Moreover, because multiple cognitive control processes operate in a unified manner to support goals [41,51], ABM training should promote their coordinated use during threat-cue exposure.

The framework, together with cognitive skill training research, therefore predicts that ABM training efficacy would be enhanced by combining several procedural features: (i) selectively attending and responding to nonthreat targets in the presence of threat cues to promote threat-distractor inhibition; (ii) explicit goal-setting: for example, specifying goals of learning attention skills for prioritising positive/calm/task-relevant nonthreat information (i.e., adaptive goal-directed ABs) while ignoring minor threat cues, and applying them in everyday situations; (iii) maximising exposure to threat cues (key feature of behavioural treatments for anxiety [67]) to facilitate habituation and reduce their aversive-motivational salience; (iv) evaluation/appraisal of threat cues as task-irrelevant (i.e., unimportant) to reduce their salience; (v) goal-directed orienting towards nonthreat target cues, irrespective of the location of threat cues; (vi) goal rehearsal: maintaining adaptive attention goals in working memory to support learning and transfer to other contexts (e.g., verbalising self-instructions to attend to positive/calm information); (vii) goal-switching: shifting between adaptive attention goals (e.g., searching for either positive or neutral information, or both simultaneously) to promote flexibility and oppose automatic salience-driven switching; (viii) extensive practice of adaptive goal-directed attention skills in presence of threat cues to encourage automatisation; (ix) feedback during training to facilitate learning; (x) using training task content relevant to daily life to promote transfer (e.g., using naturalistic stimuli, such as diverse everyday nonthreat scenes, as goal-relevant targets); and (xi) variation in training task content (e.g., task difficulty) to increase engagement with training.

Key Features of Conventional and Alternative ABM Methods

Lack of consensus regarding why conventional ABM threat-avoidance training has inconsistent effects (discussed earlier) has encouraged the development of various alternative methods which have preliminary data suggesting efficacy, for example gamified ABM [20], adaptive ABM [21], card game-based person–identity matching [68], attention feedback awareness and control training (A-FACT) [18], gaze-contingent music-reward therapy [69], emotional face visual search training [70–74], and enhanced positive search training [75,76] (Table 2). It is beyond the scope of this article to describe these in detail, and we therefore focus on key features.

Each method presents task-irrelevant threat cues (e.g., threat words, angry faces, aversive scenes) and nonthreat targets (e.g., dot probes, arrows, happy faces, positive/calm scenes), and requires participants to respond to nonthreat targets. In most ABM training methods, nonthreat targets are more likely to appear in different locations from threat cues, which encourages attention-orienting away from threat. An exception is A-FACT, which assumes that anxious individuals have unstable ABs. It uses a visual probe task in which probes are equally likely to replace threat and nonthreat cues (as in control attention training), and discourages orienting towards or away from threat by providing feedback (based on response times to target probes) to encourage stable responding to probes, and to improve cognitive control over unstable ABs.

Another notable difference between ABM training methods is whether the nonthreat target and task-irrelevant threat cues appear sequentially or simultaneously. In several methods the nonthreat target appears after the threat cue has disappeared (conventional ABM threat-avoidance training, gamified ABM, A-FACT). In other methods the nonthreat targets and threat

Table 2. Some Key Features of ABM Training Methods

	ABM training task (type of task and requirements)	Nonthreat target is likely to appear in a different location from the threat cue (promotes orienting away from threat)	Nonthreat target and threat cue appear simultaneously (promotes threat-distractor inhibition)	Explicit training goals (promotes goal-directed cognitive control)
Conventional ABM				
Conventional ABM threat-avoidance training (MacLeod *et al*. 2002) [4]	Visual probe task: detect target probes (dots) which are more likely to appear in a different location than the preceding threat cue	✓	×	×
Other ABM methods				
Gamified ABM (based on ABM threat-avoidance training; Dennis and O'Toole, 2014) [20]	Modified visual probe task: track the trail (target) which follows smiling rather than angry cartoon faces	✓	×	×
Adaptive ABM (Amir *et al*. 2016) [21]	Spatial-cueing task: detect target probes which are more likely to appear in a different location than threat words, and in the same location as positive words	✓	×	✓ Goal: to reduce AB to threat, and increase AB to positive
Attention feedback awareness and control training (A-FACT; Zvielli *et al*. 2015) [18]	Modified visual probe task: respond quickly to target dot probes regardless of whether the preceding threat cue is in the same or a different location	x	×	✓ Goal: to reduce the effect of threat on attention
Person–identity matching task (Notebaert *et al*. 2015) [68]	Card game-based task requiring person–identity matching judgments: discriminate happy face pairs (same/different person); ignore angry faces	✓	✓	×
Gaze-contingent music-reward therapy (Lazarov *et al*. 2017) [69]	Eye-tracking face arrays: pleasant music plays when gazing at neutral faces rather than disgust faces	✓	✓	×
Emotional face visual search training (Dandeneau *et al*. 2007) [70]	Visual search of face arrays: detect smiling faces, ignore negative faces	✓	✓	×
Enhanced positive search training (adapted from emotional face visual search training; Waters *et al*. 2015) [75]	Visual search of picture arrays: detect positive/calm pictures (diverse naturalistic scenes); ignore negative/threat pictures (plus goal-rehearsal, goal-switching)	✓	✓	✓ Goal: to learn skills of looking for good and calm cues

distractors are presented simultaneously (gaze-contingent music-reward therapy, person–identity matching, emotional face visual search training, enhanced positive search training), which should promote goal-directed inhibitory attention control and threat-distractor inhibition.

Several ABM training methods explicitly inform participants of the training goals, and this should also facilitate goal-directed cognitive control (adaptive ABM, A-FACT, enhanced positive search training). However, goals vary across methods. In A-FACT, the goal is to reduce ABs in orienting towards or away from threat, and participants are instructed to use feedback on probe response times to reduce the influence of threat on attention. In adaptive ABM, the explicit goals are to encourage orienting towards positive and away from threat cues, which participants repeatedly practice on a probe-based spatial cueing task. In enhanced positive search training, participants are informed that the goal is to learn adaptive attention skills, such as 'look for good' and 'look for calm', which can be used in challenging situations. Training involves searching for positive and neutral/calm pictures embedded in arrays of negative and threat-related pictures (Figure 1).

Enhanced positive search training arose from emotional face visual search training which involves searching for smiling/happy faces in arrays of angry/frowning faces. However, there are notable differences: enhanced positive search training includes explicit goal-setting ('look for good', 'look for calm'), goal rehearsal (verbalisation of these goals), goal-switching (searching for either positive or neutral/calm cues, or both simultaneously), diverse nonthreat targets (everyday objects and scenes), and varied task demands (e.g., variable array sizes, number of targets). These features were added to enhance engagement with training, acquisition and retention of attention skills, and transfer to everyday situations [75].

Novel ABM training methods commonly provide feedback to promote learning; for example, feedback on correct/incorrect responses, response time measures of ABs, or require correct responses before training advances (gamified ABM, adaptive ABM, person–identity matching, A-FACT, enhanced positive search training). In gaze-contingent music-reward therapy, pleasant music plays when participants look at neutral, but not negative faces, presented together in picture arrays. Participants are not explicitly informed of this response–reward contingency, or of specific training goals, but may deduce them from feedback during training.

Regarding clinical efficacy, only conventional ABM threat-avoidance training has been extensively evaluated in high-anxiety individuals, with disappointing results, as noted earlier. Evidence for the therapeutic efficacy of alternative ABM training methods is limited. Preliminary nonclinical studies report short-term positive effects (e.g., reduced stress reactivity after single-session training) with several methods (A-FACT, gamified ABM, person–identity matching, emotional face visual search training) [18,20,68,70]. Multi-session emotional face visual search training has mixed effects on nonclinical adolescent anxiety, with problems of poor compliance possibly owing to insufficient goal engagement [71,73,74]. Clinical studies which evaluate multi-session ABM training in individuals with anxiety disorders report anxiety reduction following adaptive ABM (uncontrolled pilot study), gaze-contingent music-reward therapy (combined with CBT), emotional face visual search training, and enhanced positive search training [21,69,72,75,76]. Enhanced positive search training was delivered at home to children with mixed anxiety disorders; therapeutic benefit was related to verbalisation of attention goals (assessed during training) and was maintained for 6 months post-training [75,76].

Concluding Remarks and Future Research Directions

This brief synopsis of research into anxiety, threat-related attention, and ABM training supports one of the three recommendations considered earlier: ABM training methods should target multiple processes underlying anxiety and threat-related ABs (Figure 2). Thus, ABM training methods, using combined procedures to target these processes (Table 1), which reduce anxiety in preliminary home-based treatment studies, warrant further evaluation in larger-scale clinical trials.

ABM training potentially offers a low-cost and easily delivered treatment option, either stand-alone or alongside other therapies. The nature and severity of anxiety symptoms vary among anxious individuals and may influence treatment outcome; for example, those with strong irrational beliefs and severe phobias may require additional intensive interventions such as CBT and therapist-guided exposure. Both CBT and exposure are thought to be effective by increasing inhibitory control over aversive salience-driven processing [77,78], and ABM training may therefore augment their effects by further supporting these processes.

Research into ABs and ABM training is informed by theory and methods from experimental psychopathology and experimental cognitive psychology. Research goals include identifying the cognitive processes modified by ABM training and their causal role in anxiety. Several studies have found that reductions in anxiety and AB measures co-occurred during ABM training, which is compatible with a causal role of AB in anxiety [5,8,17]. However, this co-occurrence is not consistently found [7], and conclusions are complicated by methodological issues (e.g., differing outcome measures, confounding variables, low-quality studies, publication bias) [9,79]. Moreover, other explanations for co-occurrence are rarely examined, such as whether ABM training modifies other processes (e.g., inhibitory attention control) which might underlie changes in anxiety and AB measures [80,81].

In addition, ABM threat-avoidance training studies often use similar tasks to both modify AB and assess AB change (e.g., probe-based spatial attention tasks are used in both ABM threat-avoidance training and AB assessment), and it is therefore unclear whether effects of training transfer to other AB measures or related cognitive functions [7,82]. A few studies have investigated whether ABM threat-avoidance training on visual probe tasks (targeting AB in threat-related orienting) reduces AB in threat-distractor interference and threat appraisal [83–87], and whether ABM training on visual search tasks reduces AB in threat-related orienting on visual probe tasks [72,75]. However, evidence of transfer is limited and inconsistent, and requires further investigation.

Another controversy concerns the effects of explicit instructions (e.g., information about training goals and content). It is helpful to distinguish between their effects in one- or two-session ABM training in nonclinical participants, versus multi-session ABM training in clinically anxious individuals, because the former may not generalise to the latter [87]. Nonclinical studies suggest that combining ABM threat-avoidance training with explicit instructions enhances AB change, and has variable effects on stress-reactivity measures [87–90]. Clinical studies of individuals with anxiety disorders suggest therapeutic benefit of combining differing ABM training methods with explicit goal-directed instructions (e.g., informing participants that training goals include learning skills of attending preferentially to positive/calm/task-relevant nonthreat information rather than to irrelevant minor threats, for use in stressful situations) [21,75,76]. Hence, this procedural variable warrants further study.

In sum, there is continuing debate about the processes underlying anxiety, threat-related ABs, and ABM training; the effectiveness of differing ABM training methods (e.g., variants of visual probe, spatial cueing, visual search, card game-based tasks); and their active constituent procedures (Tables 1,2). ABM training research may advance by (i) assessing differing manifestations of ABs (initial orienting, attention maintenance, threat avoidance, threat-distractor interference, AB variability); (ii) assessing other cognitive variables in the framework, for example general inhibitory attention control, threat evaluation/appraisal, and switching [26,44,45,52,80–82,85,91–97]; and (iii) testing theory-driven predictions regarding effective training procedures (see Outstanding Questions).

AB assessment methods include visual probe, spatial cueing, modified Stroop, flanker, and visual search tasks [6,7,12,19,35,53–55,86,98–100]. One research challenge is the limited reliability of AB indices derived from manual response times, which may reflect measurement problems and the variability of anxiety-related ABs, as discussed earlier [19,56–58,98]. Thus, there is a need to use more sophisticated methods which may prove to be more sensitive and reliable than manual response-time measures such as eye-tracking and neural indices of threat-related orienting, attention maintenance, and threat-distractor inhibition [e.g., free-viewing eye-tracking, antisaccade, N2pc (N2 posterior contralateral), SPCN (sustained posterior contralateral negativity), or fMRI; assessed during visual probe and other attention tasks] [53,92,101–111].

This article has focused on cognitive processes underlying anxiety, ABs, and ABM training. This cognitive perspective is complemented by neuroimaging studies of neural correlates of threat processing in anxiety. Such research links anxiety with dysfunctional interactions among multiple brain regions, including the salience network (supporting automatic threat evaluation/detection, and spanning amygdala/insula/frontal regions) and executive control network (supporting goal-directed activity, and spanning frontal/parietal regions) [110–115]. Research investigating the effects of ABM training on neural functioning in anxiety is in its infancy, and implicates regions involved in threat salience evaluation, attention, and cognitive control (e.g., amygdala, insula, frontal regions) [110]. Dysfunctional connections between these regions may influence treatment outcome [109,110].

A promising development is use of network-based methods to examine neural processes underlying emotion–cognition relationships and psychopathology [116–118]. This may elucidate how anxiety and threat-related ABs are supported by reciprocal interactions between large-scale brain networks, such as the salience and executive control networks, and their highly interconnected core components, for example amygdala and insula, that are implicated in automatic threat salience evaluation and salience-driven switching [48,109,110,112–119].

Moreover, network-based methods may clarify, at a cognitive-behavioural level of analysis, relationships among anxiety symptoms, threat-related ABs, and associated cognitive processes (e.g., salience evaluation, inhibition, alerting, orienting, switching) [120,121]. Anxiety and ABs may emerge from an imbalance between threat salience evaluation and cognitive control processes, described at both cognitive and neural network levels [115,118–121]. Thus, abnormal anxiety may be reduced by interventions that promote adaptive balanced functioning within the cognitive system as a whole, for example by strengthening goal-directed cognitive control to inhibit threat-hypersensitive salience-driven influences on information processing. Network-based methods may reveal complex relationships between core anxiety symptoms, cognitive and neural variables ('nodes') in multi-level networks, the stability of such relationships over time, and their modification by interventions such as ABM training [120–122]. Thus,

Outstanding Questions

Which ingredients of ABM training are effective in reducing anxiety (e.g., responding to nonthreat targets embedded among threat-distractors, orienting towards nonthreat cues and away from threat, awareness of training goals and relevance to everyday situations)? Is it more effective for ABM training to use combined procedures, which target multiple processes (Table 1), rather than using one procedure that targets a specific manifestation of AB?

Does the therapeutic effect of ABM training depend on the type of anxiety disorder (e.g., generalised distress versus fear disorders) and threat severity? For example, might ABM training procedures, which promote goal prioritisation of nonthreat information and inhibition of processing minor threat cues (e.g., threat images and words), be more helpful for generalised anxiety than for severe phobic anxiety triggered by highly feared stimuli?

Are there multiple separate causes of imbalance between salience-driven and goal-directed cognitive control processes, which may differ across anxious individuals, and result in abnormal anxiety and variable ABs (e.g., threat-hypersensitive automatic salience evaluation, overactive salience-driven switching, inadequate inhibitory attention control, dysfunctional reason-based appraisal)?

What are the similarities and differences between the effects of ABM training and other anxiety treatments (e.g., CBT, exposure, medication) on cognitive variables identified in the framework (e.g., threat salience evaluation, goal-directed inhibitory attention control, automatic orienting to threat)?

Does a similar conceptual framework apply to reward-related psychopathologies such as drug addiction and overeating: in other words, do these disorders emerge from imbalance between automatic reward-salience evaluation and goal-directed cognitive control processes? If so, might ABM training methods that similarly combine multiple goal-directed training procedures (Table 1) be useful in treating those disorders?

network approaches may complement conventional methods in experimental psychopathology to clarify the cognitive mechanisms underlying anxiety and facilitate development of effective treatment options for anxiety disorders.

Acknowledgments

We are grateful to Allison Waters who developed enhanced positive search training [75,76] in collaboration with Melanie Zimmer-Gembeck, Michelle Craske, Daniel Pine, and ourselves.

References

1. Craske, M.G. and Stein, M.B. (2016) Anxiety. *Lancet* 388, 3048–3059
2. Olatunji, B.O. *et al.* (2010) Efficacy of cognitive behavioral therapy for anxiety disorders: a review of meta-analytic findings. *Psychiatr. Clin. North Am.* 33, 557–577
3. Williams, M. *et al.* (1988) *Cognitive Psychology and Emotional Disorders.* (1st edn), Wiley
4. MacLeod, C. *et al.* (2002) Selective attention and emotional vulnerability: assessing the causal basis of their association through the experimental manipulation of attentional bias. *J. Abnorm. Psychol.* 111, 107–123
5. MacLeod, C. and Clarke, P.J.F. (2015) The attentional bias modification approach to anxiety intervention. *Clin. Psychol. Sci.* 3, 58–78
6. Mogg, K. and Bradley, B.P. (2016) Anxiety and attention to threat: cognitive mechanisms and treatment with attention bias modification. *Behav. Res. Ther.* 87, 76–108
7. Mogg, K. *et al.* (2017) Attention bias modification (ABM): review of effects of multisession ABM training on anxiety and threat-related attention in high-anxious individuals. *Clin. Psychol. Sci.* 54, 698–717
8. MacLeod, C. and Grafton, B. (2016) Anxiety-linked attentional bias and its modification: illustrating the importance of distinguishing processes and procedures in experimental psychopathology research. *Behav. Res. Ther.* 86, 68–86
9. Cristea, I.A. *et al.* (2015) Efficacy of cognitive bias modification interventions in anxiety and depression: meta-analysis. *Br. J. Psychiatry* 206, 7–16
10. Cristea, I.A. *et al.* (2015) Practitioner review: cognitive bias modification for mental health problems in children and adolescents: a meta-analysis. *J. Child Psychol. Psychiatry Allied Discip.* 56, 723–734
11. Heeren, A. *et al.* (2015) Attention bias modification for social anxiety: a systematic review and meta-analysis. *Clin. Psychol. Rev.* 40, 76–90
12. Van Bockstaele, B. *et al.* (2014) A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychol. Bull.* 140, 682–721
13. Price, R.B. *et al.* (2016) Pooled patient-level meta-analysis of children and adults completing a computer-based anxiety intervention targeting attentional bias. *Clin. Psychol. Rev.* 50, 37–49
14. Mogoaşe, C. *et al.* (2014) Clinical efficacy of attentional bias modification procedures: an updated meta-analysis. *J. Clin. Psychol.* 70, 1133–1157
15. Liu, H. *et al.* (2017) Effects of cognitive bias modification on social anxiety: a meta-analysis. *PLoS One* 12, 1–24
16. Jones, E.B. and Sharpe, L. (2017) Cognitive bias modification: a review of meta-analyses. *J. Affect. Disord.* 223, 175–183
17. Grafton, B. *et al.* (2017) Confusing procedures with process when appraising the impact of cognitive bias modification on emotional vulnerability. *Br. J. Psychiatry* 211, 266–271
18. Zvielli, A. *et al.* (2016) Targeting biased emotional attention to threat as a dynamic process in time: Attention Feedback Awareness and Control Training (A-FACT). *Clin. Psychol. Sci.* 4, 287–298
19. Amir, I. *et al.* (2016) (De)Coupling of our eyes and our mind's eye: a dynamic process perspective on attentional bias. *Emotion* 53, 1689–1699
20. Dennis, T.A. and O'Toole, L.J. (2014) Mental health on the go. *Clin. Psychol. Sci.* 2, 576–590
21. Amir, N. *et al.* (2016) A pilot study of an adaptive, idiographic, and multi-component attention bias modification program for social anxiety disorder. *Cogn. Ther. Res.* 40, 661–671
22. Öhman, A. (1993) Fear and anxiety as emotional phenomena: clinical phenomenology, evolutionary perspectives, and information-processing mechanisms. In *Handbook of Emotions* (Lewis, M. and Haviland, J., eds), pp. 511–536, The Guilford Press
23. Beck, A.T. and Clark, D.A. (1997) An information processing model of anxiety: automatic and strategic processes. *Behav. Res. Ther.* 35, 49–58
24. Derryberry, D. and Rothbart, M.K. (1997) Reactive and effortful processes in the organization of temperament. *Dev. Psychopathol.* 9, 633–652
25. Cisler, J.M. and Koster, E.H.W. (2010) Mechanisms of attentional biases towards threat in anxiety disorders: an integrative review. *Clin. Psychol. Rev.* 30, 203–216
26. Eysenck, M.W. *et al.* (2007) Anxiety and cognitive performance: attentional control theory. *Emotion* 7, 336–353
27. Lonigan, C.J. *et al.* (2004) Temperament, anxiety, and the processing of threat-relevant stimuli. *J. Clin. Child Adolesc. Psychol.* 33, 8–20
28. Bar-Haim, Y. *et al.* (2007) Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychol. Bull.* 133, 1–24
29. Mogg, K. and Bradley, B.P. (1998) A cognitive motivational analysis of anxiety. *Behav. Res. Ther.* 36, 809–848
30. Mathews, A. and Mackintosh, B. (1998) A cognitive model of selective processing in anxiety. *Cogn. Res. Ther.* 22, 539–560
31. Williams, M. *et al.* (1997) *Cognitive Psychology and Emotional Disorders.* (2nd edn), Wiley
32. Waters, A.M. and Craske, M.G. (2016) Towards a cognitive-learning formulation of youth anxiety: a narrative review of theory and evidence and implications for treatment. *Clin. Psychol. Rev.* 50, 50–66
33. Bar-Haim, Y. (2010) Research review: attention bias modification (ABM): a novel treatment for anxiety disorders. *J. Child Psychol. Psychiatry Allied Discip.* 51, 859–870
34. Hedger, N. *et al.* (2016) Are visual threats prioritized without awareness? A critical review and meta-analysis involving 3 behavioral paradigms and 2696 observers. *Psychol. Bull.* 142, 1–123
35. Teachman, B.A. *et al.* (2012) Automaticity in anxiety disorders and major depressive disorder. *Clin. Psychol. Rev.* 32, 575–603
36. Shechner, T. and Bar-Haim, Y. (2016) Threat monitoring and attention-bias modification in anxiety and stress-related disorders. *Curr. Dir. Psychol. Sci.* 25, 431–437
37. Salum, G.A. *et al.* (2013) Threat bias in attention orienting: evidence of specificity in a large community-based study. *Psychol. Med.* 43, 733–745

38. Yiend, J. *et al.* (2015) Mechanisms of selective attention in generalized anxiety disorder. *Clin. Psychol. Sci.* 3, 758–771
39. Waters, A.M. *et al.* (2014) Biased attention to threat in paediatric anxiety disorders (generalized anxiety disorder, social phobia, specific phobia, separation anxiety disorder) as a function of 'distress' versus 'fear' diagnostic categorization. *Psychol. Med.* 44, 607–616
40. Petersen, S.E. and Posner, M.I. (2012) The attention system of the human brain: 20 years after. *Annu. Rev. Neurosci.* 35, 73–89
41. Duncan, J. (2010) The multiple-demand (MD) system of the primate brain: mental programs for intelligent behaviour. *Trends Cogn. Sci.* 14, 172–179
42. Diamond, A. (2013) Executive functions. *Annu. Rev. Psychol.* 64, 135–168
43. Corbetta, M. and Shulman, G.L. (2002) Control of goal-directed and stimulus-driven attention in the brain. *Nat. Rev. Neurosci.* 3, 215–229
44. Miyake, A. *et al.* (2000) The unity and diversity of executive functions and their contributions to complex 'frontal lobe' tasks: a latent variable analysis. *Cogn. Psychol.* 41, 49–100
45. Miyake, A. and Friedman, N.P. (2012) The nature and organization of individual differences in executive functions. *Curr. Dir. Psychol. Sci.* 21, 8–14
46. Ochsner, K.N. and Gross, J.J. (2005) The cognitive control of emotion. *Trends Cogn. Sci.* 9, 242–249
47. Pessoa, L. and Adolphs, R. (2010) Emotion processing and the amygdala: from a 'low road' to 'many roads' of evaluating biological significance. *Nat. Rev. Neurosci.* 11, 773–783
48. Menon, V. and Uddin, L.Q. (2010) Saliency, switching, attention and control: a network model of insula function. *Brain Struct. Funct.* 214, 655–887
49. Vuilleumier, P. (2015) Affective and motivational control of vision. *Curr. Opin. Neurol.* 28, 29–35
50. Roelofs, K. (2017) Freeze for action: neurobiological mechanisms in animal and human freezing. *Philos. Trans. R. Soc. B* 372, 20160206
51. Gazzaley, A. and Nobre, A.C. (2012) Top-down modulation: bridging selective attention and working memory. *Trends Cogn. Sci.* 16, 129–135
52. Snyder, H.R. *et al.* (2015) Advancing understanding of executive function impairments and psychopathology: bridging the gap between clinical and cognitive approaches. *Front. Psychol.* 6, 328
53. Armstrong, T. and Olatunji, B.O. (2012) Eye tracking of attention in the affective disorders: a meta-analytic review and synthesis. *Clin. Psychol. Rev.* 32, 704–723
54. Fox, E. *et al.* (2001) Do threatening stimuli draw or hold visual attention in subclinical anxiety? *J. Exp. Psychol. Gen.* 130, 681–700
55. Williams, J.M. *et al.* (1996) The emotional Stroop task and psychopathology. *Psychol. Bull.* 120, 3–24
56. Rodebaugh, T.L. *et al.* (2016) Unreliability as a threat to understanding psychopathology: the cautionary tale of attentional bias. *J. Abnorm. Psychol.* 125, 840–851
57. Schmukle, S.C. (2005) Unreliability of the dot probe task. *Eur. J. Pers.* 19, 595–605
58. Waechter, S. *et al.* (2014) Measuring attentional bias to threat: reliability of dot probe and eye movement indices. *Cogn. Res. Ther.* 38, 313–333
59. Algom, D. *et al.* (2004) A rational look at the emotional Stroop phenomenon: a generic slowdown, not a Stroop effect. *J. Exp. Psychol. Gen.* 133, 323–338
60. Derryberry, D. and Reed, M.A. (2002) Anxiety-related attentional biases and their regulation by attentional control. *J. Abnorm. Psychol.* 111, 225–236
61. Frensch, P. and Runger, D. (2003) Implicit learning. *Curr. Dir. Psychol. Sci.* 12, 13–18
62. Sun, R. *et al.* (2005) The interaction of the explicit and the implicit in skill learning: a dual-process approach. *Psychol. Rev.* 112, 159–192
63. Healy, A.F. *et al.* (2014) Training principles to advance expertise. *Front. Psychol.* 5, 2012–2015
64. Burke, L.A. and Hutchins, H.M. (2007) Training transfer: an integrative literature review. *Hum. Resour. Dev. Rev.* 6, 263–296
65. Locke, E. and Latham, G. (2006) New directions in goal-setting theory. *Curr. Dir. Psychol.* 15, 265–269
66. Koster, E.H.W. *et al.* (2009) Introduction to the special section on cognitive bias modification in emotional disorders. *J. Abnorm. Psychol.* 118, 1–4
67. McNally, R.J. (2007) Mechanisms of exposure therapy: how neuroscience can improve psychological treatments for anxiety disorders. *Clin. Psychol. Rev.* 27, 750–759
68. Notebaert, L. *et al.* (2015) Validation of a novel attentional bias modification task: the future may be in the cards. *Behav. Res. Ther.* 65, 93–100
69. Lazarov, A. *et al.* (2017) Gaze-contingent music reward therapy for social anxiety disorder: a randomized controlled trial. *Am. J. Psychiatry* 174, 649–656
70. Dandeneau, S.D. *et al.* (2007) Cutting stress off at the pass: reducing vigilance and responsiveness to social threat by manipulating attention. *J. Pers. Soc. Psychol.* 93, 651–666
71. De Voogd, E.L. *et al.* (2014) Visual search attentional bias modification reduced social phobia in adolescents. *J. Behav. Ther. Exp. Psychiatry* 45, 252–259
72. Waters, A.M. *et al.* (2013) Attention training towards positive stimuli in clinically anxious children. *Dev. Cogn. Neurosci.* 4, 77–84
73. De Voogd, E.L. *et al.* (2016) Online attentional bias modification training targeting anxiety and depression in unselected adolescents: short- and long-term effects of a randomized controlled trial. *Behav. Res. Ther.* 87, 11–22
74. De Voogd, E.L. *et al.* (2017) Online visual search attentional bias modification for adolescents with heightened anxiety and depressive symptoms: a randomized controlled trial. *Behav. Res. Ther.* 92, 57–67
75. Waters, A.M. *et al.* (2015) Look for good and never give up: a novel attention training treatment for childhood anxiety disorders. *Behav. Res. Ther.* 73, 111–123
76. Waters, A. *et al.* (2016) A preliminary evaluation of a home-based, computer-delivered attention training treatment for anxious children living in regional communities. *J. Exp. Psychopathol.* 7, 511–527
77. Clark, D.A. and Beck, A.T. (2010) Cognitive theory and therapy of anxiety and depression: convergence with neurobiological findings. *Trends Cogn. Sci.* 14, 418–424
78. Sotres-bayon, F. *et al.* (2006) Brain mechanisms of fear extinction: historical perspectives on the contribution of prefrontal cortex. *Biol. Psychiatry* 60, 329–336
79. Cristea, I.A. *et al.* (2017) Invited commentary on . . . Confusing procedures with process in cognitive bias modification research. *Br. J. Psychiatry* 211, 272–274
80. Heeren, A. *et al.* (2015) Does attention bias modification improve attentional control? A double-blind randomized experiment with individuals with social anxiety disorder. *J. Anxiety Disord.* 29, 35–42
81. McNally, R.J. *et al.* (2013) Attention bias modification for reducing speech anxiety. *Behav. Res. Ther.* 51, 882–888
82. Hertel, P.T. and Mathews, A. (2011) Cognitive bias modification: past perspectives, current findings, and future applications. *Perspect. Psychol. Sci.* 6, 521–536
83. Everaert, J. *et al.* (2015) Attention bias modification via single-session dot-probe training: failures to replicate. *J. Behav. Ther. Exp. Psychiatry* 49, 5–12
84. Khanna, M.M. *et al.* (2016) Attention training normalises combat-related post-traumatic stress disorder effects on emotional

Stroop performance using lexically matched word lists. *Cogn. Emot.* 30, 1521–1528

85. Bowler, J.O. *et al.* (2017) Asymmetrical transfer effects of cognitive bias modification: modifying attention to threat influences interpretation of emotional ambiguity, but not vice versa. *J. Behav. Ther. Exp. Psychiatry* 54, 239–246
86. van Bockstaele, B. *et al.* (2017) Limited generalisation of changes in attentional bias following attentional bias modification with the visual probe task. *Cogn. Emot.* 31, 369–376
87. Grafton, B. *et al.* (2014) When ignorance is bliss: explicit instruction and the efficacy of CBM-A for anxiety. *Cogn. Ther. Res.* 38, 172–188
88. Lazarov, A. *et al.* (2017) The effects of training contingency awareness during attention bias modification on learning and stress reactivity. *Behav. Ther.* 48, 638–650
89. Krebs, G. *et al.* (2010) The effect of attention modification with explicit vs. minimal instructions on worry. *Behav. Res. Ther.* 48, 251–256
90. Nishiguchi, Y. *et al.* (2015) Explicitly guided attentional bias modification promotes attentional disengagement from negative stimuli. *Emotion* 15, 731–741
91. Ferguson, M. and Zayas, V. (2009) Automatic evaluation. *Curr. Dir. Psychol. Sci.* 18, 362–366
92. Berggren, N. and Derakshan, N. (2013) Attentional control deficits in trait anxiety: why you see them and why you don't. *Biol. Psychol.* 92, 440–446
93. Fan, J. *et al.* (2002) Testing the efficiency and independence of attentional networks. *J. Cogn. Neurosci.* 14, 340–347
94. Mogg, K. *et al.* (2015) Attention network functioning in children with anxiety disorders, attention-deficit/hyperactivity disorder and non-clinical anxiety. *Psychol. Med.* 45, 2633–2646
95. Mauss, I.B. and Robinson, M.D. (2009) Measures of emotion: a review. *Cogn. Emot.* 23, 209–237
96. Britton, J.C. *et al.* (2011) Development of anxiety: the role of threat appraisal and fear learning. *Depress. Anxiety* 28, 5–17
97. Angelidis, A. *et al.* (2016) Frontal EEG theta/beta ratio as an electrophysiological marker for attentional control and its test–retest reliability. *Biol. Psychol.* 121, 49–52
98. Kruijt, A.W. *et al.* (2016) Capturing dynamics of biased attention: are new attention variability measures the way forward. *PLoS One* 11, 1–22
99. Mogg, K. *et al.* (2008) Effects of threat cues on attentional shifting, disengagement and response slowing in anxious individuals. *Behav. Res. Ther.* 46, 656–667
100. Lichtenstein-Vidne, L. *et al.* (2017) Attentional bias in clinical depression and anxiety: the impact of emotional and non-emotional distracting information. *Biol. Psychol.* 122, 4–12
101. Holmes, A. *et al.* (2014) Electrophysiological evidence for greater attention to threat when cognitive control resources are depleted. *Cogn. Affect. Behav. Neurosci.* 14, 827–835
102. Reutter, M. *et al.* (2017) The N2pc component reliably captures attentional bias in social anxiety. *Psychophysiology* 54, 519–527
103. Reinholdt-Dunne, M.L. *et al.* (2012) Anxiety and selective attention to angry faces: an antisaccade study. *J. Cogn. Psychol.* 24, 54–65
104. Fox, E. *et al.* (2008) Trait anxiety modulates the electrophysiological indices of rapid spatial orienting towards angry faces. *Neuroreport* 19, 259–263
105. Boehme, S. *et al.* (2015) Neural correlates of emotional interference in social anxiety disorder. *PLoS One* 10, 1–15
106. Herting, M.M. *et al.* (2017) Test–retest reliability of longitudinal task-based fMRI – implications for developmental studies. *Dev. Cogn. Neurosci.* Published online July 13, 2017. http://dx.doi.org/10.1016/j.dcn.2017.07.001
107. Britton, J.C. *et al.* (2013) Training-associated changes and stability of attention bias in youth: implications for attention bias modification treatment for pediatric anxiety. *Dev. Cogn. Neurosci.* 4, 52–64
108. Lazarov, A. *et al.* (2016) Social anxiety is related to increased dwell time on socially threatening faces. *J. Affect. Disord.* 193, 282–288
109. White, L.K. *et al.* (2017) Complementary features of attention bias modification therapy and cognitive-behavioral therapy in pediatric anxiety disorders. *Am. J. Psychiatry* 174, 775–784
110. Wiers, C.E. and Wiers, R.W. (2017) Imaging the neural effects of cognitive bias modification training. *Neuroimage* 151, 81–91
111. Okon-Singer, H. (2018) The role of attention bias to threat in anxiety: mechanisms, modulators and open questions. *Curr. Opin. Behav. Sci.* 19, 26–30
112. Seeley, W.W. *et al.* (2007) Dissociable intrinsic connectivity networks for salience processing and executive control. *J. Neurosci.* 27, 2349–2356
113. Bishop, S.J. (2007) Neurocognitive mechanisms of anxiety: an integrative account. *Trends Cogn. Sci.* 11, 307–316
114. McMenamin, B.W. *et al.* (2014) Network organization unfolds over time during periods of anxious anticipation. *J. Neurosci.* 34, 11261–11273
115. MacNamara, A. *et al.* (2016) Aberrant spontaneous and task-dependent functional connections in the anxious brain. *Biol. Psychiatry Cogn. Neurosci. Neuroimaging* 1, 278–287
116. Pessoa, L. (2017) A network model of the emotional brain. *Trends Cogn. Sci.* 21, 357–371
117. Okon-Singer, H. *et al.* (2015) The neurobiology of emotion–cognition interactions: fundamental questions and strategies for future research. *Front. Hum. Neurosci.* 9, 1–14
118. Menon, V. (2011) Large-scale brain networks and psychopathology: a unifying triple network model. *Trends Cogn. Sci.* 15, 483–506
119. Sylvester, C.M. *et al.* (2012) Functional network dysfunction in anxiety and anxiety disorders. *Trends Neurosci.* 35, 527–535
120. Heeren, A. and McNally, R.J. (2016) An integrative network approach to social anxiety disorder: the complex dynamic interplay among attentional bias for threat, attentional control, and symptoms. *J. Anxiety Disord.* 42, 95–104
121. Hofmann, S.G. *et al.* (2016) A complex network perspective on clinical science. *Perspect. Psychol. Sci.* 11, 597–605
122. Guloksuz, S. *et al.* (2017) Application of network methods for understanding mental disorders: pitfalls and promise. *Psychol. Med.* 47, 2743–2752