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Role of Attention in the Regulation of Fear and Anxiety

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Abstract
Emotion regulation makes use of specific aspects of attention and executive functions that are critical for the development of adaptive social functioning, and perturbations in these processes can result in maladaptive behavior and psychopathology. Both involuntary and voluntary attention processes have been examined at both the behavioral and the neural levels and are implicated in the maintenance of fearful or anxious behaviors. However, relatively little is known about how these attention processes come to influence emotional behavior across development. The current review summarizes the extant literature on the links between voluntary and involuntary attention processes and the role that these attention processes have in the etiology, maintenance, and regulation of anxious behavior.

Over the course of development, children learn how to control their emotions across diverse contexts and situations [1]. While toddlers are notoriously poor at regulating their emotions, most children have acquired the skills necessary to regulate their behavior and emotions in an adaptive fashion by the end of the preschool period. However, there is great variability between children in their ability to regulate their emotions, and perturbations in this ability can put children at risk for maladaptive behavior and psychopathology [2]. A child's temperamental reactivity can play an important role in the development and efficiency of emotion regulation [3]. The development of processes associated with regulation can exacerbate or reduce these reactive tendencies in children. As such, interactions between temperamental reactivity and the development of emotion regulation may be particularly important for the development of adaptive social behavior. The current review focuses on the role of fearful temperaments as a risk factor for the development of psychopathology [4]. Infants and young children who display heightened fearful reactivity coupled with poor emotion regulation may be at risk for the development of anxiety.

Multiple levels of attention play an important role in adaptive emotional regulation [5]. Many researchers believe that attention processes are critical for adaptive emotion regulation; however, the evidence demonstrating associations between components of attention, emotion regulation, and developmental outcomes is modest at best. In addition, we know relatively little as to how these attention processes (such as attention shifting) come to affect and regulate emotional behavior. Perhaps the best evidence relating the development of certain attention processes to emotion regulation comes from research investigating the regulation of fearful or anxious

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behaviors in children and adults [6]. This research has identified the role that attention plays in both the maintenance and regulation of fearful or anxious behaviors and has described the underlying neural circuitry and, to some extent, the development of the circuits that support the attention processes that act to maintain or modulate fear responses [7].

The importance of attention and its role in the development of adaptive emotion regulation has been clearly articulated by Posner and Rothbart [8]. Their model, which focuses on both the involuntary and voluntary aspects of attention and their respective roles in the regulation of emotion, is a useful heuristic for approaching the study of the development of emotion regulation. First, such a model can be investigated on both the behavioral and neural levels. Second, there is a large literature linking both automatic and voluntary aspects of attention to anxious behaviors in adults [9]. One can utilize these studies to hypothesize about the emergence, maintenance, and change in fearful or anxious behaviors in early development. Third, from a developmental perspective, it is reasonable to posit that automatic aspects of attention come 'on line' earlier than voluntary ones, thereby providing a window for examining developmental changes in attention and their underlying neural circuitry.

In this paper, we review behavioral and neural studies describing both involuntary and voluntary attention processes associated with temperamental fear and anxious behaviors. We first highlight the involuntary attention processes that prioritize the processing of threat, and demonstrate that perturbed processing of threat can be seen even in young children. Second, we discuss the role that both voluntary and involuntary attention play in the regulation and maintenance of anxious behaviors in temperamentally reactive individuals and suggest avenues of intervention for adults and children with anxiety disorders.

Models of Attention

Posner described a neurobehavioral model of attention that involves three distinct processes – alerting, orienting, and executive attention. The alerting system is involuntary and involved in achieving, increasing, and maintaining an alert state [10], which can help prepare an individual to process high-priority stimuli in the environment [10]. Alerting can be in the form of a general alert state or a state that is specific to the preparation of attention for processing task-related information [11]. Although increased alerting is associated with enhanced processing of a target as indexed by faster reaction times, it is often accompanied by decreases in response effectiveness as indexed by lower accuracy rates. This suggests that although increased alertness may lead to the selection of a target for further processing, it is often in response to a decreased, and sometimes insufficient, amount of information [10].

Orienting includes both involuntary attention, as when the onset of a cue automatically captures one's attention, and voluntary orienting, as when one voluntarily focuses attention on a specific stimulus [12]. The orienting system selects the information in the environment to which one needs to attend, which subsequently leads to greater efficiency in processing of that stimulus [10]. The act of orienting involves several steps: the disengagement of attention from one location, the shifting of attention toward a second location, the engaging of attention to the new location, and an inhibition of the return of attention to the previous location [10]. Orienting typically involves the process of selective attention, characterized by the focusing of one's attention on a specific object or location over other objects or locations in the environment [13].

The executive attention system involves the voluntary control of attention [5] and often serves to regulate involuntary attention processes (i.e. alerting and orienting). This system is thought to be involved in filtering out unimportant or irrelevant information, monitoring, planning, switching attention between tasks or types of information, generating novel responses, and overriding dominant responses in favor of performing a subdominant response [14].

In addition to understanding the type of attention system being activated, it is also important to understand the neural basis of attention activation, as this distinction may have important implications for attention problems in highly reactive individuals. Stimulus-driven (i.e., bottom-up) processes are activated by the stimulus' salience, which influences the speed with which the stimulus is attended to and processed. Top-down processes refer to when an individual's goals, experience, or intentions influence how attention is allocated [15]. Hence, the salience of a stimulus and the behavioral or psychological relevance of the stimulus both have strong influences on attention. Stimuli in the environment constantly compete for attention resources and the stimulus that 'wins' the competition is ultimately determined by the interactions between stimulus-driven and top-down attention processes [16]. Therefore, if communication between

these two attention processes is perturbed, attention may be preferentially allocated to irrelevant negative stimuli in the environment, creating maladaptive attention biases. These maladaptive attention biases may then lead to a cascade of problems later in development.

Interaction of Attention and Emotion

Individuals differ in the efficiency of their attention systems and the specific processing patterns that accompany these systems. Specifically, anxious individuals appear to have involuntary attention biases towards threat-related information in the environment, which have been associated with the maintenance and etiology of anxiety disorders [17, 18]. Although some theories suggest that anxious individuals have a general heightened alert state, often referred to as hyper-vigilance [19], there is little behavioral evidence to support this claim. Thus, the following review will focus on aspects of biased orienting processes in anxious individuals.

Attention to Threat: Behavior

An important and adaptive function of attention is the act of scanning the environment for relevant or important information which can then be attended, encoded, and interpreted [20] and directly affects our thoughts and actions [21]. If an individual has an increased sensitivity to threat or places undue importance on threat, that individual will likely scan the environment for threat-related information [22]. Visual search tasks, assessing how quickly and accurately an individual can locate a target amongst an array of irrelevant distracter stimuli [23], have shown systematic differences between anxious and non-anxious individuals when threat-related stimuli are present. Ohman et al. [24], for example, had participants look for either a fear-relevant target (snakes and spiders) in an array of neutral stimuli (mushrooms and flowers) or a neutral target in an array of fear-relevant stimuli. When the target was fear-relevant, all participants were faster at detecting the threat-related target regardless of the location of the target or number of distracters. However, participants who reported high levels of fear towards specific fear-relevant stimuli (e.g. a fear of snakes), leading them to a place increased importance on such stimuli, showed enhanced target detection of that specific fear-relevant stimulus. Comparable differences in threat-related detection patterns have also been found between anxious and non-anxious children [25].

In the presence of threatening and nonthreatening information, anxious individuals selectively attend toward the threatening information – a pattern not typically seen in nonanxious individuals. The dot-probe task has proved particularly useful in the examination of biased allocation of attention in anxious children and adults [26, 27]. During the dot-probe task, both a threatening (i.e. angry or fearful) and a neutral stimulus are presented simultaneously, followed by a target probe that appears in the location previously occupied by one of the two stimuli. The participant is asked to respond to the target as quickly and accurately as possible. Target detection latencies provide a useful temporal measure of an individual's attention allocation. Anxious individuals reliably respond more slowly than non-anxious individuals when the target appears in the vicinity of the neutral face compared to when the target appears in the vicinity of the angry face [27, for review, see 28]. This bias to orient to threatening information has also been shown when emotion stimuli are presented subliminally, suggesting that this bias is automatic or occurs involuntarily [29].

Anxious children also show biased allocation of attention to threat in both supra- and subliminal conditions of the dot-probe [30]. In a recent study by Roy and colleagues [31], attention bias to threat using the dot-probe task was examined in a large group of children and adolescents with generalized anxiety disorder, separation anxiety disorder, or social anxiety disorder. Results revealed that anxious children, regardless of disorder, showed an attention bias to threat compared to non-anxious children. Using a similar paradigm, Perez-Edgar et al. [32] found that adolescents who were characterized as behaviorally inhibited during early childhood showed increased attention bias to threat compared to noninhibited adolescents. Furthermore, the magnitude of the threat bias was shown to moderate the relation between childhood temperament and maternally reported social withdrawal.

The emotional Stroop is another task often used to examine biased selective attention in anxious individuals. In this task, individuals are presented with words printed in different colors, and are asked to name the color of the word as quickly as possible, which requires diverting attention resources from processing the meaning of the word. When the printed words vary in emotional valence, anxious individuals show a greater slowing of reaction times to threat-related words relative to neutral words than do non-anxious individuals [for review, see 33]. This pattern of results has been found with anxious children and adults [34] and during both supra- and subliminal task conditions [35]. Although the Stroop effect

is often found with general emotion-related or negative words, anxious individuals display greater enhancement of the Stroop interference effect for anxiety-related words [36], where the level of anxiety is related to the magnitude of their threat-related interference [37]. Taken together, both the dot-probe data and emotional Stroop data illustrate that anxious children and adults selectively orient their attention towards threatening information in the environment even when such information is irrelevant to the task, devoting more resources and time to processing such information.

Once anxious adults and children have allocated their attention to a source of threat, they display difficulties disengaging from the threat. Using a spatial cueing paradigm in which an emotional stimuli cued the presentation of a target stimulus, Fox et al. [38] found that on trials in which an angry face was an invalid cue, high-state-anxious participants took longer to respond to the target compared to when a neutral or happy face was an invalid cue, a pattern that was not found in trait-anxious individuals. Similarly, in a task using emotionally valenced pictures, anxious individuals took longer to disengage their attention from threat-related pictures compared to neutral and positive pictures [39]. Georgiou et al. [40] presented subjects, at fixation, with fearful, sad, happy, or neutral facial expressions in the center of the screen. Anxious participants were slower to respond to a target than nonanxious participants only when the cue target was a fearful face. Therefore, not only do anxious individuals display enhanced detection of and orientation to threat stimuli, they also display difficulty in disengaging attention away from threat. The disruption of this disengagement system has been hypothesized to play a significant role in the etiology and maintenance of anxiety disorders [40].

Recent evidence suggests that consistent involuntary biases (i.e. faster detection, biased selective attention, and difficulty disengaging) illustrated in individuals at risk for anxiety disorders, such as adolescents with behavioral inhibition, likely put them at risk for the development of psychopathology [6, 41]. However, these involuntary aspects of attention can be counteracted by top-down influences that can voluntarily inhibit or control attention. The ability to control attention allows an individual to focus on task-relevant information in the environment, while filtering out task-irrelevant threatening information [42]. Derryberry and Reed [6] examined how an individual's ability to control their attention directly related to their involuntary or reactive bias. In a dot-probe task using brief stimulus presentations, where an individual would presumably not have the time to voluntarily control their attention, anxious individuals showed a greater bias to attend to negative information than nonanxious individuals, regardless of their level of attention control. However, at longer stimulus presentations, an individual's level of attention control moderated the link between anxiety and attention bias to threat: although anxious individuals with poor attention control still displayed an attention bias to threat, those with good attention control no longer showed this bias. This moderation of attention bias to threat by attention control has also been shown in children [41]. Thus, efficient attention regulative processes may decrease the association between a fearful reactive temperament and the development of psychopathology by reducing an individual's involuntary biases towards threat and anxious cognitions [41].

An individual's experiences, intentions, and goals can also exert influence over aspects of involuntary attention [43]. Many of the biases in involuntary attention processes that prioritize threat may stem from top-down influences due to the sensitivity temperamentally fearful children have to possible threats in their environment. The importance placed on potential threats may influence the anxious child to continually monitor their environment for possible sources of threat, which, in turn, leads to attention patterns that likely prioritize that threat once it is detected [44]. In other words, top-down goals can 'weight' certain information in the environment so that these stimuli can receive priority processing. Thus, the ability to inhibit the importance one places on threat in the environment will likely reduce the occurrence of threat-related processing biases. For example, although anxious children show a specific threat-related Stroop effect [45], there is some evidence to suggest that all children, despite their level of anxiety, show an emotional Stroop effect [46]. However, with age, nonanxious children appear to learn how to inhibit prioritizing the processing of threat, whereas their anxious peers do not [47]. Moreover, even if threat remains salient to anxious individuals, the ability to flexibly switch to a new, more adaptive, goal, such as monitoring the environment for safety cues once threat has been detected, may help reduce perturbed attention processing. Thus, the inability to inhibit unnecessary threat processing, or to reduce the top-down influences that prioritize threat information, leads to continual biased threat processing and places temperamentally fearful children at risk for developing anxiety disorders.

Rather than being unaware of efficient strategies to regulate their anxiety, anxious children seem to have an inability to properly execute such strategies [48]. Hender-

son et al. [49] found that when shy adolescents had higher levels of attention control, they had lower levels of social anxiety. Similarly, Muris et al. [50] showed that children's self-report of attention control was inversely related to psychological symptom ratings. The combination of high negative reactivity and poor voluntary attention control put a child at an increased risk to experience anxiety frequently and for longer durations. Moreover, proper recruitment of higher-level cognitive functions may be negatively impacted by involuntary threat-related attention biases [5], such that the more anxious an individual, the more inefficient his or her higher-level cognitive functioning. For example, if an anxious individual prioritizes the initial processing of threat, and does not disengage from that threat, she will have limited cognitive resources available to reinterpret the situation as less threatening. Thus, poor voluntary control of attention allows biased processing to remain, maintaining an anxious state, and limits the efficiency of higher-level cognitive control.

Attention to Threat: Neurobiology

The amygdala is part of the brain's limbic system and it has long been associated with emotion processing, particularly the processing of fear stimuli [51]. When presented with threatening stimuli (e.g. angry or fearful faces), anxious individuals display increased amygdala activation compared to non-anxious individuals [52]. The amygdala has been proposed to have both rapid and slow information-processing pathways [53], which may reflect neural mechanisms related to involuntary and voluntary attention to threat stimuli, respectively. Therefore, the amygdala and related circuitry may underlie individual differences in attention biases to threat.

Studies have shown that the amygdala even responds to threat stimuli when participants do not consciously observe the stimuli [54, 55]. Specifically, an increased amygdala response was observed when participants were presented with either masked fearful faces [55] or fearful eyes [54] for an imperceptible period of time (17–22 ms) compared to neutral faces and eyes. Additional studies have shown that the amygdala is activated in response to threatening distracters even when attention is directed towards another task [56]. In general, these results suggest that the amygdala responds automatically to threatening stimuli and does not require voluntary attention processes [but for an alternate view, see 57]. However, few studies have investigated individual differences in amygdala response to automatic threat processing. In one study, Etkin and colleagues [58] found that self-report of trait anxiety was positively correlated with amygdala response to subliminally-presented fearful faces. In another study, high-anxious individuals displayed greater amygdala activation to threatening stimuli, compared to low-anxious individuals, when paying attention to another task [59].

In addition, Kagan et al. [60] suggested that a hypersensitive amygdala underlies the hypervigilance to novelty seen in behaviorally inhibited children. Studies investigating individual differences in involuntary attention processes between behaviorally inhibited and noninhibited adolescents have used evoked-response potentials (ERPs) to examine novelty detection. Although these ERP studies do not directly measure amygdala activity, there is some suggestion that these measures are related to activation in the amygdala as well as several other areas in the brain [61]. Using an auditory oddball task in which frequent (standard) and infrequent (deviant) tones were presented, Bar-Haim et al. [62] found that behaviorally inhibited children show a decreased response to presentations of the deviant tone relative to noninhibited children, suggesting differential processing of new information. Using a somewhat different paradigm in which novel complex sounds (e.g. dog barking, cork popping) were embedded in with the standard and deviant tones, Marshall and colleagues [63] examined novelty detection in 9-month-old infants selected for high motor/high distress reactivity at 4 months of age. Compared to infants who displayed heightened positive reactivity to novelty, the negatively reactive infants showed increased neural activation to the deviant versus the standard stimulus. Thus, as early as 9 months of age, and most probably earlier, infants react differently to novelty based upon their temperamental biases.

Differences in reaction to novelty may also moderate the relation between temperament and psychopathology. A recent study by Reeb-Sutherland et al. [64] demonstrated that increased neural response to novel complex sounds as measured by the P3, a component associated with the orienting response [65], moderated the relation between behavioral inhibition and anxiety. Specifically, behaviorally inhibited adolescents with large P3 responses to novelty were at greater risk for an anxiety diagnosis compared to those with small P3 responses.

A number of recent studies, both in adolescents and adults, have demonstrated that the willful direction of attention in the presence of threatening stimuli activates prefrontal regions thought to be involved in attention control, which in turn appear to down-regulate activation of the amygdala. Many of these tasks involve cogni-

tive reappraisal, or altering the cognitive processing of the threatening information during or after visual attention. In some of these studies, participants were asked either to think specifically about the threat-relevant features of a stimulus, or to think about features that were threat-irrelevant [66]. In other studies, participants were asked to either focus on the images in the picture by thinking about them happening to themselves (in order to up-regulate emotion) or by generating a more positive interpretation of what might be happening in the scene (in order to down-regulate emotion) [67]. These cognitive appraisal techniques have been shown to change self-reported affect, physiological response, and amygdala activation in the direction of regulation, and up-regulate the lateral prefrontal cortex, medial prefrontal cortex (mPFC), and dorsal anterior cingulate cortex.

Consistent with these data suggesting that executive attention influences emotional processing, a number of recent fMRI studies indicate that amygdalar activation can be influenced by top-down attention or cognitive manipulations [for a review, see 67]. In one study [68], individuals viewed a series of negative pictures, and were asked to either passively view the images, or to maintain their emotional response to them for several seconds after the image disappeared. In both conditions, amygdala activation was the same during presentation of the stimulus, but in the period after the image had disappeared, the amygdala response was significantly higher in participants who were asked to maintain their emotional response compared to those who passively viewed the images. This suggests that using consciously evoked cognitive mechanisms to process a previously viewed emotional image leads to sustained activation of the amygdala throughout the time of emotional processing.

To date, only a handful of studies have examined individual differences in the intersection of attention and emotional circuitry in adolescents [69–71]. In one such study, Monk et al. [71] presented a dot-probe task with two different durations of presentation of the threat faces to adolescents with anxiety disorders. Consistent with the notion that areas of prefrontal cortex might down-regulate amygdala activation as a result of automatic or involuntary attention responses to threat, when the faces were presented at 17 ms and masked, the researchers found amygdala activation to the faces, with a positive correlation between amount of activation and ratings of anxiety, but when the faces were presented for a long duration (500 ms), subjects showed increased ventrolateral PFC activation with a negative correlation between anxiety symptoms and activation (greater activation was related to fewer symptoms). In two studies, separate populations of adolescents, who differed in their temperamental reactivity, were presented with threatening and neutral faces and asked to either passively view the faces, evaluate their own levels of fear (a cognitive emotional regulation technique), or evaluate the width of the face's nose (an attention redirection technique with low attention load). In both studies, the temperamentally reactive populations showed enhanced, not reduced, amygdala response during subjective fear ratings. These results in adolescents may be due to the use of young populations, which may have less-developed prefrontal connections to the amygdala than adults, or perhaps due to the fact that these populations were highly emotionally reactive, which may be associated with poor attention and cognitive control of emotion. Indeed, in tasks where individuals were asked to perform a task while ignoring emotional distracters, high-anxious individuals showed less activation of PFC regions, suggesting that they may have impaired prefrontal control in situations involving threat [59].

The findings presented above on the neurobiology involved in attention processes suggest that (1) the amygdala is involved in both early automatic attention processing and later cognitive attention processing of threatening stimuli; (2) the prefrontal cortex is involved in voluntary attention processes, specifically in regulating amygdala activation to threatening stimuli, and (3) the circuitry between the prefrontal cortex and the amygdala leading to downregulation during active emotion regulation is perturbed in anxious individuals. In anxious individuals, a set of core features exist that permit a repetitive cycle of anxiety to take place. Enhanced amygdala sensitivity to threatening stimuli leads to enhanced vigilance and attention capture by these stimuli. These stimuli are then processed for a longer time before disengagement. Decreased prefrontal activation, most probably from the area of ventrolateral PFC, leads to reduced attention control, thus maintaining cognitive processing of the threatening stimuli even after they are no longer present in the visual field. These patterns of visual and cognitive processing of threat maintain an increased level of amygdala activation, which, in turn, makes detection of another potentially threatening stimulus more likely, generating a cycle of heightened vigilance and anxiety.

Conclusion and Future Directions

This review has highlighted the role that both involuntary and voluntary attention processes play in the etiology and maintenance of anxiety. The reactive biases in attention that accompany temperamentally fearful children increase their experience of anxiety and anxiety-related processing. The inability to modulate these reactive attention biases enhances a heightened state of anxiety placing subjects at risk for the development of psychopathology. Much of the previous research examining the relations between attention and anxious behaviors primarily focused on either the reactive, involuntary, aspects of attention or the voluntary control of attention. Little research has examined both involuntary and voluntary attention processes together. Given the evidence presented here, it is clear that anxious children and adults have perturbed attention processes at multiple levels of attention. Thus, integrating multiple stages of attention processing in this area of research is important to fully understand the relation between temperamental fear and the development of anxiety.

In addition, mechanisms by which these attention biases develop and lead to states of anxiety are not yet described. Further investigation into the development of involuntary attention biases and voluntary attention control, and how these two processes interact over the course of development will be helpful in the examination of such mechanisms. Specifically, it is important to examine the stability and malleability of such biases throughout development to understand how attention processes relate to the development of emotional regulation and, ultimately, the manifestation of anxiety disorders.

The evidence presented above describes the importance of both involuntary and voluntary attention processing in the etiology of anxiety. Given the importance of higher-level attention control in reducing biased attention processing and dampening anxious states, helping anxious individuals improve attention control may be an important mechanism for reducing the development of psychopathology. Components of voluntary attention are highly amenable to improvement through training across development [72]. Therefore, it may be possible to have children who are at high risk for developing anxiety disorders undergo attention training to help them reduce their involuntary attention biases and, indirectly, their anxious states. There may also be a strong learning component to involuntary attention biases, and, as such, these involuntary biases may be fairly malleable and susceptible to training [17, 18]. Throughout development, anxious children are hypersensitive to learning about threat in their environment [73]. Facilitated learning about threat by these children may result in subsequent attention bias to the threat and difficulties disengaging from the newly acquired threatening information [73]. Thus, training individuals to no longer prioritize the processing of threat, but sources of safety, also may be a useful treatment for children at risk for developing anxiety disorders [17, 18].

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