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Threats, rewards, and attention deployment in anxious youth and adults: An eye tracking study

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ABSTRACT

The current study examines anxiety and age associations with attention allocation and physiological response to threats and rewards. Twenty-two healthy-adults, 20 anxious-adults, 26 healthy-youth, and 19 anxious-youth completed two eye-tracking tasks. In the Visual Scene Task (VST), participants' fixations were recorded while they viewed a central neutral image flanked by two threatening or two rewarding stimuli. In the Negative Words Task (NWT), physiological response was measured by means of pupil diameter change while negative and neutral words were presented. For both tasks, no interaction was found between anxiety and age-group. In the VST, anxious participants avoided the threatening images when groups were collapsed across age. Similarly, adults but not adolescents avoided the threatening images when collapsed across anxiety. No differences were found for rewarding images. In NWT, all subjects demonstrated increase in pupil dilation after word presentation. Only main effect of age emerged with stronger pupil dilation in adults than children. Finally, maximum pupil change was correlated with threat avoidance bias in the scene task. Gaze patterns and pupil dilation show that anxiety and age are associated with attention allocation to threats. The relations between attention and autonomic arousal point to a complex interaction between bottom-up and top-down processes as they relate to attention allocation.

1. Introduction

Stimuli that elicit emotional responses capture attention, which in turn facilitates adaptive behavioral and physiological responses in normative populations. However, in patients with anxiety disorders, dysregulated emotional sensitivity is associated with aberrant patterns of attention capture, and this may in turn contribute to pathological responding (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van, 2007; Mogg & Bradley, 1998). Although anxiety disorders typically first emerge during childhood and adolescence, research examining the effect of attention allocation on anxiety has primarily been conducted in adults, using stimuli developed for adults. The current study was designed to address potential developmental differences in attention allocation among anxious youth and adults using two novel eye-tracking tasks.

Although threat-related attention biases have consistently been found in anxious adults and children (Shechner et al., 2012), the direction and strength of biases are more variable in pediatric than adult patients (Bar-Haim, 2010). This is not surprising given the prominent age related changes in executive functioning, in brain structures that support attention control, in emotional regulation strategies and in individual learning histories (Luna, Padmanabhan, & O'Hearn, 2010; Paus, 2005). This developmental difference is particularly important when examining the effects of longer exposure of threatening stimuli on attention, a process that involves both involuntary immediate responses as well as attention processes which are under greater voluntary control that emerge with longer stimulus durations (LeDoux, 1996). Whereas the vigilance response is believed to be reflexive the avoidance response is generally thought to be under greater voluntary control. Avoidance may also be a partially learned response which becomes more established with experience. Therefore, while we expected similar initial orienting response across development, we expected the avoidance response to be more strongly and consistently expressed in adults. In this regard, a common theoretical explanation described by the

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Table 1
Sample demographics.

Whole sample ($n = 87$)	Anxious		Healthy	
	Adult ($n = 20$)	Youth ($n = 19$)	Adult ($n = 22$)	Youth ($n = 26$)
GAD	4			
SoPh	3	3		
SAD		3		
SoPh & GAD	10	4		
SoPh & Other		1		
GAD & PD	3			
SAD & GAD		1		
SoPh & SAD		1		
GAD & SpecPh		1		
SoPh & GAD & SpecPh		2		
SoPh & SAD & GAD		1		
SoPh & SAD & SpecPh		1		
SoPh & GAD & SpecPh		1		
Self-reported SCARED total		25.26 (10.62)		9.82 (7.60)
Parent-reported SCARED total		36.79 (14.52)		4.82 (5.57)
Self-reported LSAS total	65.33 (25.23)		19.62 (21.19)	
Mean age (years)	28.98 (8.37)	12.08 (2.93)	28.78 (5.59)	13.03 (2.87)
Age range (years)	19.25–50.42	8.08–17.67	21.42–39.67	8.08–17.50
Number female (% of sample)	17 (85.0)	9 (47.4)	10 (45.5)	11 (55.0)
2 WASI sub-scales IQ	115.75 (10.71)	107.83 (12.22)	116.85 (12.41)	110.67 (9.94)

Note: GAD—generalized anxiety disorder, SoPh—social phobia, SAD—separation anxiety, PD—panic disorder, SpecPh—specific phobia, SCARED— Self-report for Childhood Anxiety Related Emotional Disorder, LSAS—Liebowitz Social Anxiety Scale, PARS—Pediatric Anxiety Rating Scale, SES—socioeconomic status. 2 WASI sub-scales are vocabulary and matrix reasoning.

vigilance–avoidance model, postulates that anxious individuals initially orient their attention towards, but then rapidly shift their attention away from threats (Mogg, Bradley, de Bono, & Painter, 1997;Waters, Kokkoris, Mogg, Bradley, & Pine, 2010). Hence, developmental differences in attention allocation are expected to affect patterns of vigilance–avoidance, which may explain the variability in threat related attention biases observed in anxious youth.

Further, current models suggest that both bottom up and top down factors influence attention allocation (Knudsen, 2007). Bottom up effects, such as threat detection, are likely related to responses in several early maturing brain regions such as the amygdala, anterior cingulate and orbitofrontal cortex. Top down factors, such as working memory, response selection and effortful shifts of attention, are likely mediated by brain regions such as the lateral prefrontal and posterior parietal cortex (Browning, Holmes, Murphy, Goodwin, & Harmer, 2010; Corbetta & Shulman, 2002; Knudsen, 2007), which are relatively late to reach functional maturity (Crone, 2009; Gogtay et al., 2004; Paus, 2005). Consequently, in mature adults with anxiety this may result in an organized goal of avoiding aversive experiences, whereas in children with anxiety this function may not be mature enough to influence attentional control (Amso & Scerif, 2015). This issue may be particularly relevant in the presence of stimuli that are highly salient (i.e., bottom up) during a specific developmental stage, as social stimuli appear to be for adolescents (Blakemore, den Ouden, Choudhury, & Frith, 2007; Blakemore & Mills, 2014; Nelson, Leibenluft, McClure, & Pine, 2005).

Eye tracking is one promising method for investigating threat-related attentional biases. Unlike the typical dot-probe task, where attention patterns are inferred based on differences in behavioral reaction times (Macleod, Mathews, & Tata, 1986), recording eye movements allows for a direct, in-vivo, measure of attention allocation. In addition, continuous recording of eye movements, as opposed to series of single dot-probe trials, could be very useful in studying the temporal changes in attention allocation over time. And yet, only four studies to date have used these methods to study attention–anxiety relations in youth (Gamble & Rapee, 2009; In-Albon, Kossowsky, & Schneider, 2010; Seefeldt, Kramer, Tuschen-Caffier, & Heinrichs, 2014; Shechner et al., 2013). While these studies varied in the exact definition of vigilance, three found differences in early but not later phases of attention. A fourth study found no bias in initial attention orientation towards negative or positive scenes, but some between-group differences emerged in later phases of stimulus display (In-Albon et al., 2010). These equivocal results may be the product of various methodological differences such as stimuli type (faces vs. scenes), presentation duration and age range.

In the present studies we used eye tracking to assess the degree to which attentional capture varies as a function of anxiety diagnosis and age. In a first study, participants passively viewed naturalistic scenes, which varied by valence (threatening vs. rewarding) and in whether they were embedded in a social context, which is highly salient during adolescence (Steinberg and Morris, 2001). As with previous eye tracking studies in anxious youth (Gamble & Rapee, 2009; In-Albon et al., 2010; Seefeldt et al., 2014; Shechner et al., 2013), visual attention was measured by patterns of eye fixation. In a second study, negative social and negative non-socially relevant words were presented in both visual and auditory domains to the same participants. Here, pupil dilation was used as an index of autonomic response to stimuli with differential emotional valence (Siegle, Steinhauer, Carter, Ramel, & Thase, 2003; Silk et al., 2007). Inclusion of both measures allowed us to independently track attention allocation and autonomic responses in the same participants.

We made the following hypotheses: (1) Anxiety will be associated with avoidance of threat related images and enhanced pupil diameter change to threatening words; (2) Age will be positively associated with attention allocation, as indexed by avoidance of threatening images, and negatively associated with pupil diameter change (because of emotional valence) across all groups; (3) Anxiety and age will interact such that greater differences in threat avoidance will be observed between anxious adults and anxious youth compared to the corresponding difference in the non-anxious groups; (4) Measures of attention (eye movement) and arousal (pupil diameter change) will be correlated in individuals across tasks.