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Relationships between attention to emotion and anxiety among a community sample of adolescents

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Abstract

Background. Attentional bias to threat has been implicated as a cognitive mechanism in anxiety disorders for youth. Yet, prior studies documenting this bias have largely relied on a method with questionable reliability (i.e. dot-probe task) and small samples, few of which included adolescents. The current study sought to address such limitations by examining relations between anxiety – both clinically diagnosed and dimensionally rated – and attentional bias to threat.

Methods. The study included a community sample of adolescents and employed eye-tracking methodology intended to capture possible biases across the full range of both automatic (i.e. vigilance bias) and controlled attentional processes (i.e. avoidance bias, maintenance bias). We examined both dimensional anxiety (across the full sample; $n = 215$) and categorical anxiety in a subset case-control analysis ($n = 100$) as predictors of biases.

Results. Findings indicated that participants with an anxiety disorder oriented more slowly to angry faces than matched controls. Results did not suggest a greater likelihood of initial orienting to angry faces among our participants with anxiety disorders or those with higher dimensional ratings of anxiety. Greater anxiety severity was associated with greater dwell time to neutral faces.

Conclusions. This is the largest study to date examining eye-tracking metrics of attention to threat among healthy and anxious youth. Findings did not support the notion that anxiety is characterized by heightened vigilance or avoidance/maintenance of attention to threat. All effects detected were extremely small. Links between attention to threat and anxiety among adolescents may be subtle and highly dependent on experimental task dimensions.

Individual differences in attentional allocation to threat are postulated to relate to the development and maintenance of anxiety disorders (Cisler & Koster, 2010). Threat-related attentional biases are characterized by either automatic or volitional attentional allocation. The vigilance attentional bias links anxiety to excessive automatic attentional orienting toward threatening stimuli (e.g. Puliafico and Kendall, 2006). Conversely, other attentional biases are believed to occur volitionally later in the time course of visual processing of stimuli. The avoidance bias suggests that individuals with anxiety volitionally shift attention away from threatening stimuli (Monk et al., 2006; Pine et al., 2005; Stirling, Eley, & Clark, 2006) whereas the maintenance bias suggests that anxiety-prone individuals fail to disengage from threatening stimuli (Fox, Russo, Bowles, & Dutton, 2001). It should be noted that avoidance of threat may also occur automatically among those with anxiety, early in the orienting stage (Gamble & Rapee, 2009). Broadly, there is accumulating evidence that anxious individuals demonstrate greater vigilance-based attentional bias than non-anxious controls, yet findings are mixed whether anxious individuals exhibit avoidance or maintenance biases during extended attentional processing (Armstrong & Olatunji, 2012; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Dudeney, Sharpe, & Hunt, 2015).

A primary method for evaluating attentional biases is the dot-probe task wherein behavioral reaction times to probes replacing threatening or non-threatening visual stimuli are recorded. Quicker reaction times toward the stimulus replaced by the probe presume greater attentional allocation; an equation assesses whether a bias toward threatening stimuli exists. A recent meta-analysis of 38 attention bias studies found evidence for the vigilance bias in children with anxiety (Dudeney et al., 2015), although interestingly the overall effect was nonsignificant for studies using the dot-probe but significant and moderately sized for those using a Stroop paradigm. While the dot-probe task frequently employs stimulus presentations of only 500 ms, studies using extended presentation times have found evidence for the avoidance bias (e.g. Brown et al., 2013). These findings lend support to attentional biases being present for anxious individuals at both the automatic and volitional levels of attentional processing.

Recent reviews have criticized the use of dot-probe tasks to measure attention and suggest that methodological aspects of this paradigm may contribute to inconsistent findings (Fu & Pérez-Edgar, 2019; MacLeod, Grafton, & Notebaert, 2019). Several studies have documented poor reliability of dot-probe tasks (Chapman, Devue, & Grimshaw, 2019; Price et al., 2015; Rodebaugh et al., 2016). Further, dot-probe tasks attempt to capture attention at a single time point and thus cannot detect biases across the full attentional time-course (Fu & Pérez-Edgar, 2019). Recent advancements have allowed researchers to use the eye-tracking methodology to assesses dynamic visual attention processes by sampling eye-gaze hundreds of times per second during the time-course of stimuli presentation. Compared to dot-probe tasks, eye-tracking has demonstrated greater reliability and sensitivity for indexing attentional biases (Price et al., 2015; Sears et al., 2018).

Findings regarding attention biases and anxiety using eye-tracking in youth populations remain mixed. Most studies employed variants of passive viewing tasks, in which participants observe sets of emotionally-valenced stimuli without task demands. One study found evidence for the vigilance bias, such that children with anxiety disorders ($n = 18$) showed a higher probability of first fixation (PFF) on fearful faces, and they did so more rapidly, compared to 15 healthy participants (Shechner et al., 2013). Seefeldt, Krämer, Tuschen-Caffier, and Heinrichs (2014) also documented a vigilance bias among children with social anxiety ($n = 30$), but only after an anxiety-induction procedure. Another study of children with separation anxiety ($n = 23$) found evidence of greater PFF on threatening pictures between 1 and 3 s of exposure, followed by avoidance of those pictures after 3 s, relative to 17 healthy peers (In-Albon, Kossowsky, & Schneider, 2010). Similarly, Wieckowski, Capriola-Hall, Elias, Ollendick, and White (2019) found that adolescents with social anxiety ($n = 42$) showed early vigilance for angry faces, but only when viewing adult face stimuli, not faces of children or adolescents. In contrast, other studies with similarly small samples (i.e. $n = 19$ and 43, respectively) have either not found evidence for greater threat avoidance in anxious youth (Shechner et al., 2017) or only found evidence of threat avoidance in anxious youth during short (i.e. 500 ms), but not long (i.e. 3000 ms) trials (Gamble & Rapee, 2009). Studies evaluating associations between attentional biases and dimensional ratings of anxiety were also mixed with either nonsignificant findings in anxious youth ($n = 67$; Price et al., 2016) or significant associations in college students ($n = 42$; Schofield, Johnson, Inhoff, and Coles, 2012). Notably, eye-tracking studies had small sample sizes and thus limited statistical power, and most did not use both dimensional and categorical approaches for assessing anxiety. Further research using eye-tracking in larger samples including both dimensional and categorical measures of anxiety is warranted.

Beyond limitations in methodology, few studies have examined relationships between attentional biases and anxiety in adolescents despite adolescence being a period of sharply greater risk for internalizing disorders (Merikangas et al., 2010). A recent review highlights the paucity of literature investigating threat-related attentional biases across developmental periods (Fu & Pérez-Edgar, 2019). The Dudeney et al. (2015) meta-analysis found that age significantly moderated attentional bias findings, such that vigilance bias effect sizes were larger in older samples of youth. The mean age in studies included in this meta-analysis ranged from 8 years to 16.5 years; however, only 12 of 38 studies included children with mean ages above 13 years and only three of those studies had a mean age above 15 years of age. Similarly, the mean ages in the eye-tracking studies reviewed above were skewed toward late childhood and early adolescence, with mean ages ranging from 9.9 to 14.40 years (Gamble & Rapee, 2009; In-Albon et al., 2010; Price et al., 2016; Shechner et al., 2013, 2017; Seefeldt et al., 2014; Wieckowski et al., 2019). Further research using eye-tracking methodology with samples of adolescents is warranted.

In summary, there are several limitations of prior studies using eye-tracking to evaluate threat-related attentional biases and anxiety. First, sample sizes across studies are typically small ($n = 17$ to 67). Second, few studies evaluated links between attentional biases and categorical and dimensional ratings of anxiety, and those that did were likely limited by sample size and restricted range of anxiety within clinical samples. Third, studies have focused heavily on childhood with a limited focus on adolescence, despite this period involving a significant increase in internalizing concerns (Merikangas et al., 2010) and despite attention biases increasing with age (Dudeney et al., 2015). Finally, few studies have featured stimuli presentations longer than 4000 ms, which may limit sensitivity to differences in volitionally controlled attentional biases.

The current study used eye-tracking technology to capture visual attention during a passive viewing emotional processing task involving extended exposures to arrays of emotional face stimuli. We investigated whether emotion-specific patterns of visual attention were associated with categorical and dimensional measures of anxiety.

Our first hypothesis was that anxiety, measured both categorically and dimensionally, would be associated with a greater PFF on angry faces. PFF has been used in previous studies to index vigilance processes (Shechner et al., 2013; Wieser, Pauli, Weyers, Alpers, & Mühlberger, 2009; e.g., Holas, Krejtz, Cypryanska, & Nezlek, 2014), as angry faces indicate threat and may be automatically prioritized for initial visual scrutiny relative to other face types. Our hypothesis was based on previous eye-tracking studies (Seefeldt et al., 2014; Shechner et al., 2013) and the large literature featuring dot-probe tasks (see Dudeney et al., 2015). Our second hypothesis was that anxiety would be associated with a shorter time to first fixation (TFF) on the angry faces. TFF to threatening stimuli has been used to index vigilance for threat (Armstrong & Olatunji, 2012) and has been found among anxious youth in a previous, smaller study (Shechner et al., 2013). We had an additional exploratory hypothesis that dimensional anxiety would be associated with greater dwell time to angry faces during early epochs of each face exposure (reflecting automatic initial orienting) but decreased dwell time during later epochs (reflecting more voluntary control of attention), indicating a pattern of early vigilance and later avoidance. We also intended to explore whether anxiety was linked to attentional dwell time toward other emotional expressions.

Method

Participants

Youth and a parent from the general community were recruited from the third, sixth, and ninth grades of public schools in the

Denver metro areas to take part in a longitudinal study in which youth were assessed at regular intervals over a 36-month period (for additional details on the study, see Hankin et al., 2015). Inclusion criteria included English fluency; exclusion criteria included autism spectrum disorder, psychosis, or intellectual/developmental disabilities. This study included 262 adolescent participants who completed the eye-tracking procedure. Of these, 215 had sufficient eye-tracking data and were included in analyses (see details below). Participants were 61.4% female, 11.2% reported ethnicity of Hispanic/Latinx, and for the race, participants reported 80.5% White, 4.2% Asian, 3.7% African American, 0.5% as American Indian, 6.0% multi-racial, and 5.1% other. Of the participating parents, 67.0% had earned a bachelor's degree or above and 14.5% of families reported receiving free/reduced lunch.

Data for the current analyses were taken from the final, 36-month in-person visit of the longitudinal study (Hankin et al., 2015), when youth were between 10 and 19 years old ($M = 15.10$, s.d. = 2.30). Those without sufficient data were not significantly different from those included in our analyses in terms of age ($t = 1.363$, $p = 0.17$) or anxiety severity ($t = -1.736$, $p = 0.08$), although they were more likely to be male ($\chi^2 = 8.94$, $p = 0.003$).

Procedure

Parents completed informed written consent for their and their teen's participation and adolescents gave written assent. An institutional review board approved all procedures and participants were compensated for participation.

Clinical Measures

Anxiety assessment

Anxiety was measured categorically using the Anxiety Disorder Interview Schedule, Child and Parent Versions (ADIS C/P; Silverman and Albano, 1996). The ADIS is a structured diagnostic interview administered by trained interviewers separately to both parent and adolescent informants. For the current study, we used anxiety diagnoses that were current at the final, 36-month appointment when the eye-tracking procedures occurred. Parent and teen interviews were reconciled with the principal investigator following a standardized procedure to arrive at best estimate DSM-IV diagnoses. Adolescents currently meeting criteria for generalized anxiety disorder (GAD) or social anxiety disorder (SAD) – the two most prevalent anxiety disorders in the sample – were included in the anxiety disorder group (participants with only specific phobia were not eligible for the anxiety group because past work suggests attentional processes to emotion work differently for specific phobia diagnoses; Bar-Haim et al., 2007).

Anxiety severity was measured dimensionally at the same visit using the 39-item self-report Multidimensional Anxiety Scale for Children (MASC) (March, 1997). The MASC possesses adequate test-retest reliability and good convergent and divergent validity (March, Parker, Sullivan, Stallings, & Conners, 1997), including in community samples of youth (Baldwin & Dadds, 2007). Each MASC item describes a symptom of anxiety and respondents indicate how true that item has been for them on a four-point scale ranging from 0 ('Never true') to 3 ('Very True'). For the current analyses, we focused on the summary total scores. Internal consistency was high ($\alpha = 0.88$).

Depressive disorders

To better characterize our sample, we used the Kiddie Schedule for Affective Disorders and Schizophrenia-Present and Lifetime version (K-SADS-PL; Kaufman et al., 1999) to measure clinical depression, including major depressive disorder and dysthymia. The K-SADS is a reliable and valid semi-structured interview administered by interviewers separately to adolescents and parents. Interviewers and graduate students were trained by PhD-level, licensed psychologists to conduct the diagnostic interviews. For the present study, only current depression diagnoses at the final, 36-month appointment were considered. Interrater reliability was good (0.91) based on approximately 20% of interviews being reviewed for reliability. Both youth and parent reports on the K-SADS were used to determine youth diagnostic status using best-estimate procedures (Klein, Dougherty, & Olino, 2005).

Eye-tracking acquisition

Eye-tracking equipment

Stimuli were presented on a 17" Tobii T120 infrared eye-tracker monitor (Tobii Technology, Stockholm, Sweden) using Tobii Studio software. Before beginning the task, youth were positioned 60 cm from the eye-tracker monitor, where they completed a 9-point calibration procedure. Data were recorded separately for both eyes, with a sampling rate of 60 Hz and a mean accuracy of 0.5° visual angle. Data from left and right eye gaze positions were averaged to determine gaze location.

Eye-tracking task

Visual attention was measured using a passive viewing task adapted from Kellough, Beevers, Ellis, and Wells (2008). This task involved the presentation of 24 trials of adult faces taken from the NimStim standardized face emotion set (www.macbrain.org/faces/index.htm). Participants were instructed to view images 'as if looking through photos in a photo album or watching television.' Each trial began with a 1-s presentation of black fixation cross in the middle of a white screen. Next, four color images of a single actor or actress' face appeared on the white background, displaying four unique expressions (i.e. neutral, happy, sad, and angry). The face stimuli were presented for 10 s each, with the still face images distributed evenly in a quadrant pattern (i.e. the upper left, upper right, lower left, and lower right quadrants). Each of the face images was 4.625 cm high × 3.625 cm wide, with 6.125 cm of white space between the center of each stimulus horizontally and 5.375 cm vertically. Each of the four emotional expressions occurred with equal frequency in all quadrants, equal numbers of male and female faces were displayed, the location of each expression type was counterbalanced across the stimulus set and trials were presented in a new random order for each participant. We did not confirm that participants were oriented to the fixation cross at picture onset.

Eye-tracking data cleaning and analysis

Tobii Studio software was used to extract and analyze eye movement data. Areas of interest were identified for each trial, corresponding with the total area and positioning of the four face images. Similar to a previous eye-tracking study with emotional face stimuli (Shechner et al., 2013), we calculated three primary variables for each emotion type: PFF, TFF, and dwell time. Fixations were defined as ⩾100 ms of continuous gaze within the boundaries of one area of interest. Trials with less than 7 s

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of total fixations (>30% data loss) were excluded from analyses and individuals with <50% usable trials (i.e. <12) were excluded from further analyses ($n = 47$). The mean number of good trials was 22.38 (s.d. = 2.77) out of 24.

To calculate PFF, we captured the emotional face type first fixated upon within each trial, then summed the total number of first fixations for each emotional face type, dividing by the total number of good trials for that participant. TFF was calculated as the time between trial initiation and the beginning of the first fixation to any of the emotion faces. Average TFF was captured for each emotion for all trials on which first fixations were made to that emotion. These values were then winsorized to the 95th percentile across all trials for each participant in order to reduce the effects of spurious outliers. The average TFF by emotion type was then calculated for all good trials. To measure dwell time, each 10-s trial was separated into 20 individual epochs of 500 ms, within which we captured fixation to each emotion face type. Dwell time values (per epoch) were winsorized to the 95th percentile for each trial then averaged across all trials to capture average dwell time by emotion type for each epoch.

Analyses

To examine relationships between attentional biases and anxiety diagnoses, we employed a case-control design. For each participant in the anxiety group (i.e. participants with an ADIS diagnosis of GAD or SAD; see above for criteria explanation), we matched a corresponding participant based on age (within 1 year) and gender who did not meet criteria for any DSM-IV diagnosis (i.e. no depression, mania, psychosis, or other anxiety disorder). The latter constituted our control group. In the anxiety group, 40% ($n = 20$) presented with a comorbid depressive disorder, 48% ($n = 24$) with comorbid specific phobia, and 6% ($n = 3$) with comorbid panic disorder. We found no differences between those included *v.* excluded from these case-control analyses in terms of gender ($\chi^2 = 0.03$, $p = 0.86$), age ($t = 0.43$, $p = 0.86$) or MASC total score ($t = 1.40$, $p = 0.16$).

We evaluated our first hypothesis that anxiety would be associated with greater PFF on angry faces using hierarchical multiple linear regression. To examine this categorically, we first entered age and gender as covariates, given that both have been associated with differences in anxiety-related threat biases (Sass et al., 2010; Shechner et al., 2012). We then added the diagnostic group as a predictor. We calculated PFF for each emotion type for each individual and ran a linear regression looking at the relationship between the diagnostic group to PFF towards angry faces. To examine our first hypothesis dimensionally, we ran the same analyses but substituted MASC total score as the independent variable. As recommended by Miller and Chapman (2001), testing relationships with and without covariates provides a more robust analysis of proposed models; thus, we also tested all models without age and gender included.

To examine our second hypothesis, we ran a separate hierarchical multiple linear regression identical to the one described previously for each emotion face type, using the diagnostic group as our predictor and TFF scores as the dependent variable, while controlling for age and gender. We next performed dimensional analyses using MASC scores as the independent variable and TFF on angry faces as the dependent variable. Models were again tested with and without age and gender covariates.

Finally, to test our exploratory hypothesis, we used two repeated measures mixed models to examine dwell time to angry faces across the duration of the trials. The first model contained the covariates of gender and age, MASC scores, time, and the interaction term between MASC scores and time. If the interaction was not significant, a second model was run with the interaction removed to examine the possible main effect of anxiety. Although not part of our hypotheses, we then ran these same models for the other three emotion face types. We then repeated these same analyses but substituted a categorical anxiety variable in place of the MASC score. Participants with a SAD or GAD diagnosis were in the anxiety group while all other participants were the comparator. This is different than our previous analyses in which we had a matched control group, however, it allowed us to use the full sample to maximize power in the multilevel model.

The distributions for all variables were tested for normality. The TFF variables for each emotion face type were found to be significantly positively skewed. We performed log transformations, and the resulting variables produced acceptable distributions for our analyses.

We conducted a power analysis to assess our ability to detect different size effects with our given sample [Power Analysis and Sample Size Software (PASS), version 15]. For dimensional analyses on hypotheses one and two (with sample size ranging from 207 to 211) the estimated power to detect a small effect ($f^2 = 0.02$), medium effect ($f^2 = 0.15$) or large effect ($f^2 = 0.35$), ranged from 0.36 to 0.37 for a small effect, 0.99 for a medium effect, and 1 for a large effect. For our categorical analyses (with sample size ranging from 98 to 100), our power to detect a small effect was 0.18, for a medium effect was 0.89, and for a large effect was 0.99. It was difficult to anticipate possible effect sizes given that previous eye-tracking studies differed from this study across several important methodological dimensions (e.g. task design, type of sample, eye-tracking variables). Nonetheless, previous studies which have found group differences in attentional bias to threatening stimuli among anxious and non-anxious pediatric samples have reported *medium* effect sizes (Gamble & Rapee, 2009; Shechner et al., 2012, 2017). Thus for medium or larger effects, this study should have been well-powered to find evidence of attentional bias linked to anxiety, however, for small effects, we would have been insufficiently powered for both dimensional and categorical analyses.

The current study was preregistered through the Open Science Framework. All preregistration documents can be accessed here: https://osf.io/dzv8t/?view_only=01807552da494dbdbe29a86f56a6165a There are some small differences between the preregistration document and the study as reported here. Note that our sample of 215 is larger than the estimated sample in the preregistration document, which was 175 participants. As we prepared the data, we learned that a larger group of participants had actually completed the eye-tracking procedure than was originally thought. In our preregistration, we also planned to use the Pubertal Development Scale (Peterson, Crockett, Richards, & Boxer, 1988) score as a covariate in our analyses, but ultimately elected to use chronological age as this resulted in less missing data.

Results

See Table 1 for descriptive statistics characterizing the sample. As shown, the Regression results described below include the covariates of age and gender. Note that regressions performed without these covariates produced nearly identical results and did not change the significance of any of the regression models.

Table 1. Sample characteristics for case-control groups and the entire sample

	Anxiety group ($n = 50$)	Healthy controls ($n = 50$)	Test statistic	p	Effect size	Full sample ($n = 215$)
Age in years (S.D.)	15.30 (2.27)	15.25 (2.30)	$t = -0.11$	0.92	$d = 0.02$	14.96 (2.30)
MASC Total (S.D.)	43.74 (13.40)	37.10 (12.80)	$t = -2.50$	0.01	$d = 0.51$	38.41 (14.37)
Proportion with Comorbid Depressive Disorder	20/50	0/50	$\chi^2 = 25$ 0.58	<0.001	n/a	35/215

Note: MASC Total, Multidimensional Anxiety Scale for Children, self-report total score.

Probability of first fixation

Figure 1*a* portrays the average mean PFF to each type of emotional face, separated by diagnostic group. Contrary to our hypothesis, we found that PFF to angry faces was not related to diagnostic group ($\beta = 0.044$, $\Delta R^2 = 0.002$, $p = 0.656$) or to dimensional self-report of anxiety severity ($\beta = 0.0002$, $\Delta R^2 = 0.002$, $p = 0.817$). Similarly, neither the diagnostic group nor anxiety severity was related to PFF on the other three emotional face types. Age and gender were not significantly related to PFF for any of the emotional face types (see Table 2).

Given that depressive diagnoses were common among our sample, and depressive disorders have been previously associated with attention biases using eye-tracking (e.g. Lazarov, Ben-Zion, Shamai, Pine, and Bar-Haim, 2018), we elected to re-run our analyses while controlling for the presence of a current depressive disorder. Adding this covariate did not significantly change the regression analyses for PFF. We also conducted a series of one-sample *t* tests to examine whether PFF was significantly different from chance (0.25) for any of the emotional faces, separately by diagnostic group, as well as across the entire sample. None of these analyses was significant at $p < 0.05$.

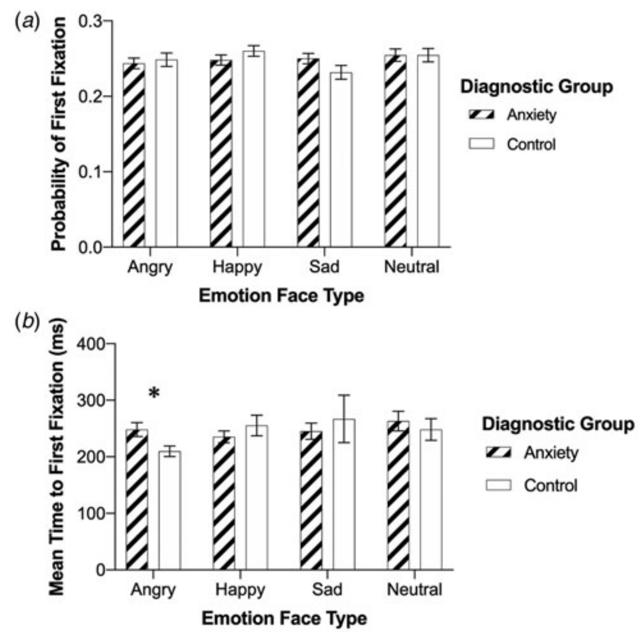

Fig. 1. (*a*) The mean PFF for each emotion face type, separated by diagnostic group. Error bars represent standard error. (*b*) The mean TFF on each emotion face type, separated by diagnostic group. Error bars represent standard error. * = statistically significant difference at $p < 0.05$.

Time to first fixation

Figure 1*b* displays the mean TFF on each type of emotional face, separated by diagnostic group. Contrary to our hypothesis, we found that individuals with anxiety disorders were slower on average to fixate on the angry faces than healthy controls ($\beta = 0.208$, $\Delta R^2 = 0.043$, $p = 0.039$), a difference of 38.4 ms per trial. Dimensional ratings of anxiety severity were not associated with TFF for angry faces ($\beta = 0.075$, $\Delta R^2 = 0.006$, $p = 0.281$). Neither diagnostic group nor dimensional anxiety severity was associated with TFF for the other emotional face types (see Table 3). In models using the diagnostic group predictor, age was significantly related to TFF on sad faces ($\beta = -0.258$, $\Delta R^2 = 0.069$, $p = 0.011$). In models with the dimensional predictor, age was significantly related to TFF for both happy ($\beta = -0.259$, $\Delta R^2 = 0.073$, $p < 0.001$) and sad faces ($\beta = -0.222$, $\Delta R^2 = 0.063$, $p = 0.001$). Gender was not significantly related to TFF in any model. Adding depression diagnosis as a covariate did slightly change our results. Namely, our previous finding, that anxious youth were slower to orient to angry faces than controls, became marginally significant ($\Delta R^2 = 0.038$, $p = 0.05$) after controlling for depression.

We also wished to examine whether TFF was different across emotions, using the entire sample as well as separately by diagnostic group. For each analysis, we employed a repeated-measures ANOVA with four-levels, one for each emotion face type. The overall model using the entire sample was marginally significant, $F_{(3,204)} = 2.64$, $p = 0.05$, partial eta$^2 = 0.08$, however none of the pairwise comparisons across emotions approached significance (all $p > 0.7$). For the separate models with non-anxious participants ($n = 48$) and those with anxiety disorders ($n = 49$), the overall models did not reach significance ($p = 0.32$ and $p = 0.13$, respectively).

Dwell time

Our analyses did not reveal the main effects of dimensional anxiety severity or of interactions between anxiety and time for dwell time to angry faces, happy faces or sad faces. We did, however, find main effects of gender ($p = 0.01$), age ($p < 0.01$) and anxiety ($p = 0.04$) to neutral faces. Least-squares means were calculated for the amount of dwell time per epoch to neutral faces, and were higher for girls ($m = 103.46$ ms, S.E.M. = 1.32) than for boys ($m = 98.12$ ms, S.E.M. = 1.69). Age was positively associated with greater dwell time to neutral faces ($B = 1.52$). There was also an interaction between time and anxiety ($p = 0.04$) on dwell time to neutral faces (see Table 4). To examine this interaction, we plotted the average dwell time to each emotional face, by epoch, for participants in the lowest and highest quartiles of dimensional anxiety severity on the MASC (Fig. 2). Participants with high

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Table 2. Hierarchical regression analysis predicting the probability of first fixation (PFF) for each emotion type from the diagnostic group and MASC total score

	PFF anger					PFF happy					PFF sad					PFF neutral				
Variable	*B* (s.e.)	*β*	*t*	*p*	ΔR^2	B (s.e.)	*β*	*t*	*p*	ΔR^2	B (s.e.)	*β*	*t*	*p*	ΔR^2	*B* (s.e.)	*β*	*t*	*p*	ΔR^2
Step 1					0.010					0.010					0.001					0.003
Gender	0.001 (0.014)	0.010	0.093	0.926		−0.003 (0.012)	−0.022	−0.211	0.833		0.004 (0.014)	0.031	0.301	0.764		0.001 (0.015)	0.008	0.074	0.942	
Age	−0.002 (0.003)	−0.099	−0.971	0.334		0.002 (0.002)	0.099	0.968	0.335		−0.001 (0.003)	−0.023	−0.225	0.822		0.001 (0.003)	0.049	0.475	0.636	
Step 2					0.002					0.015					0.026					0.000
Gender	0.001 (0.014)	0.010	0.094	0.925		−0.002 (0.012)	−0.021	−0.210	0.834		0.004 (0.014)	0.031	0.301	0.764		0.001 (0.015)	0.008	0.073	0.942	
Age	−0.002 (0.003)	−0.100	−0.972	0.333		0.002 (0.002)	0.098	0.957	0.341		−0.001 (0.003)	−0.021	−0.209	0.835		0.001 (0.003)	0.049	0.472	0.638	
Anxiety diagnosis	0.005 (0.011)	0.045	0.446	0.656		0.012 (0.010)	0.124	1.227	0.223		−0.018 (0.012)	−0.160	−1.588	0.116		0.000 (0.012)	−0.001	−0.011	0.991	
Step 1					0.001					0.012					0.004					0.011
Gender	0.003 (0.009)	0.027	0.391	0.696		−0.013 (0.009)	−0.096	−1.388	0.167		0.007 (0.008)	0.060	0.853	0.395		0.007 (0.009)	0.056	0.810	0.419	
Age	−0.001 (0.002)	−0.021	−0.305	0.761		−0.001 (0.002)	−0.045	−0.650	0.516		0.000 (0.002)	0.015	0.220	0.826		0.002 (0.002)	0.082	1.184	0.238	
Step 2					0.000					0.000					0.005					0.002
Gender	0.003 (0.009)	0.025	0.347	0.729		−0.012 (0.009)	−0.095	−1.347	0.179		0.008 (0.008)	0.072	1.018	0.310		0.006 (0.009)	0.049	0.699	0.486	
Age	−0.001 (0.002)	−0.021	−0.298	0.766		−0.001 (0.002)	−0.045	−0.651	0.515		0.000 (0.002)	0.013	0.193	0.847		0.002 (0.002)	0.083	1.197	0.233	
MASC Total	0.000 (0.000)	0.016	0.232	0.817		0.000 (0.000)	−0.008	−0.113	0.910		0.000 (0.000)	−0.075	−1.072	0.285		0.000 (0.000)	0.042	0.603	0.547	

Note: PFF, Probability of first fixation; MASC Total, Multidimensional Anxiety Scale for Children, self-report total score. For each regression using anxiety diagnosis, ($n = 100$); for each regression using MASC Total ($n = 211$).

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Table 3. Hierarchical regression analysis predicting time to first fixation for each emotion type from the diagnostic group and MASC total score

	TFF anger					TFF happy					TFF sad					TFF neutral				
Variable	*B* (s.e.)	*B*	*t*	*p*	ΔR^2	*B* (s.e.)	*β*	*t*	*p*	ΔR^2	*B* (s.e.)	*β*	*t*	*p*	ΔR^2	*B* (s.e.)	*β*	*t*	*p*	ΔR^2
Step 1					0.007					0.020					0.069					0.019
Gender	−0.043 (0.059)	−0.075	−0.730	0.467		−0.015 (0.035)	−0.044	−0.432	0.666		−0.010 (0.041)	−0.024	−0.239	0.812		−0.046 (0.039)	−0.122	−1.182	0.240	
Age	0.005 (0.011)	0.048	0.469	0.640		−0.008 (0.006)	−0.126	−1.227	0.223		−0.020 (0.008)	−0.258	−2.598	0.011		−0.003 (0.007)	−0.047	−0.453	0.651	
Step 2					0.043					0.005					0.000					0.009
Gender	−0.043 (0.058)	−0.075	−0.739	0.462		−0.015 (0.035)	−0.044	−0.427	0.671		−0.010 (0.041)	−0.024	−0.238	0.813		−0.046 (0.039)	−0.122	−1.180	0.241	
Age	0.005 (0.011)	0.046	0.454	0.651		−0.008 (0.007)	−0.126	−1.228	0.223		−0.020 (0.008)	−0.258	−2.585	0.011		−0.003 (0.007)	−0.048	−0.464	0.644	
Anxiety diagnosis	0.099 (0.047)	0.208	2.091	0.039		−0.020 (0.029)	−0.070	−0.693	0.490		0.003 (0.034)	0.010	0.098	0.922		0.031 (0.032)	0.097	0.955	0.342	
Step 1					0.018					0.073					0.063					0.014
Gender	−0.061 (0.031)	−0.135	−1.952	0.052		−0.014 (0.020)	−0.048	−0.699	485		−0.031 (0.023)	−0.090	−1.325	0.187		−0.004 (0.019)	−0.014	−0.195	0.846	
Age	0.000 (0.007)	−0.004	−0.060	0.953		−0.016 (0.004)	−0.259	−3.802	0.000		−0.016 (0.005)	−0.222	−3.279	0.001		−0.007 (0.004)	−0.144	−1.627	0.105	
Step 2					0.006					0.001					0.004					0.001
Gender	−0.066 (0.032)	−0.148	−2.105	0.037		−0.016 (0.020)	−0.053	−0.762	0.447		−0.035 (0.024)	−0.100	−1.455	0.147		−0.002 (0.019)	−0.007	−0.105	0.916	
Age	0.000 (0.007)	−0.002	−0.032	0.975		−0.016 (0.004)	−0.258	−3.775	0.000		−0.016 (0.005)	−0.221	−3.254	0.001		−0.007 (0.004)	−0.115	−1.636	0.103	
MASC Total	0.001 (0.001)	0.075	1.081	0.281		0.000 (0.001)	0.029	0.418	0.676		0.001 (0.001)	0.062	0.906	0.366		0.000 (0.001)	−0.038	−0.542	0.589	

Note: TFF, Time to first fixation; MASC, Multidimensional Anxiety Scale for Children, self-report total score. For the TFF anger regression using anxiety diagnosis ($n = 100$); For the TFF happy regression using anxiety diagnosis ($n = 99$); For the TFF sad regression using anxiety diagnosis ($n = 100$); For the TFF neutral regression using anxiety diagnosis ($n = 98$); for each regression using MASC Total ($n = 211$). For the TFF anger regression using MASC Total ($n = 211$); For the TFF happy regression using MASC Total ($n = 207$); For the TFF sad regression using MASC Total ($n = 211$); For the TFF neutral regression using MASC Total ($n = 209$).

Table 4. Repeated measures mixed models examining the association of MASC scores (4a) or anxiety diagnosis (4b) with the duration of attention to face stimuli by emotion type

	Angry				Happy				Sad				Neutral			
Effect	Num df	Den df	*F* Value	*PR* > *F*	Num df	Den df	*F* Value	*PR* > *F*	Num df	Den df	*F* Value	*PR* > *F*	Num df	Den df	*F* Value	*PR* > *F*
4a																
Time	19	3990	22.37	<0.01	19	3990	17.85	<0.01	19	3990	3.89	<0.01	19	3971	3.69	<0.01
Gender	1	207	1.02	0.31	1	207	7.51	<0.01	1	207	1.94	0.16	1	207	6.20	0.01
Age	1	207	1.06	0.31	1	207	0.54	0.46	1	207	0.98	0.32	1	207	11.36	<0.01
MASC Total	1	207	0.69	0.41	1	207	0.86	0.35	1	207	0.04	0.85	1	207	4.43	0.04
MASC × Time interaction													19	3971	1.61	0.04
4b																
Time	19	3990	22.09	<0.01	19	3990	17.84	<0.01	19	3990	3.93	<0.01	19	3990	18.49	<0.01
Gender	1	207	2.33	0.13	1	207	7.57	<0.01	1	207	3.46	0.06	1	207	8.23	0.01
Age	1	207	0.23	0.63	1	207	0.61	0.43	1	207	2.18	0.14	1	207	9.76	<0.01
ANX DX	1	207	0.56	0.45	1	207	0.79	0.38	1	207	0.22	0.64	1	207	3.70	0.06
ANX DX × Time interaction																

Note: Only significant interactions are shown; MASC Total, Multidimensional Anxiety Scale for Children, self-report total score; ANX DX, presence of social anxiety disorder or generalized anxiety disorder diagnosis.

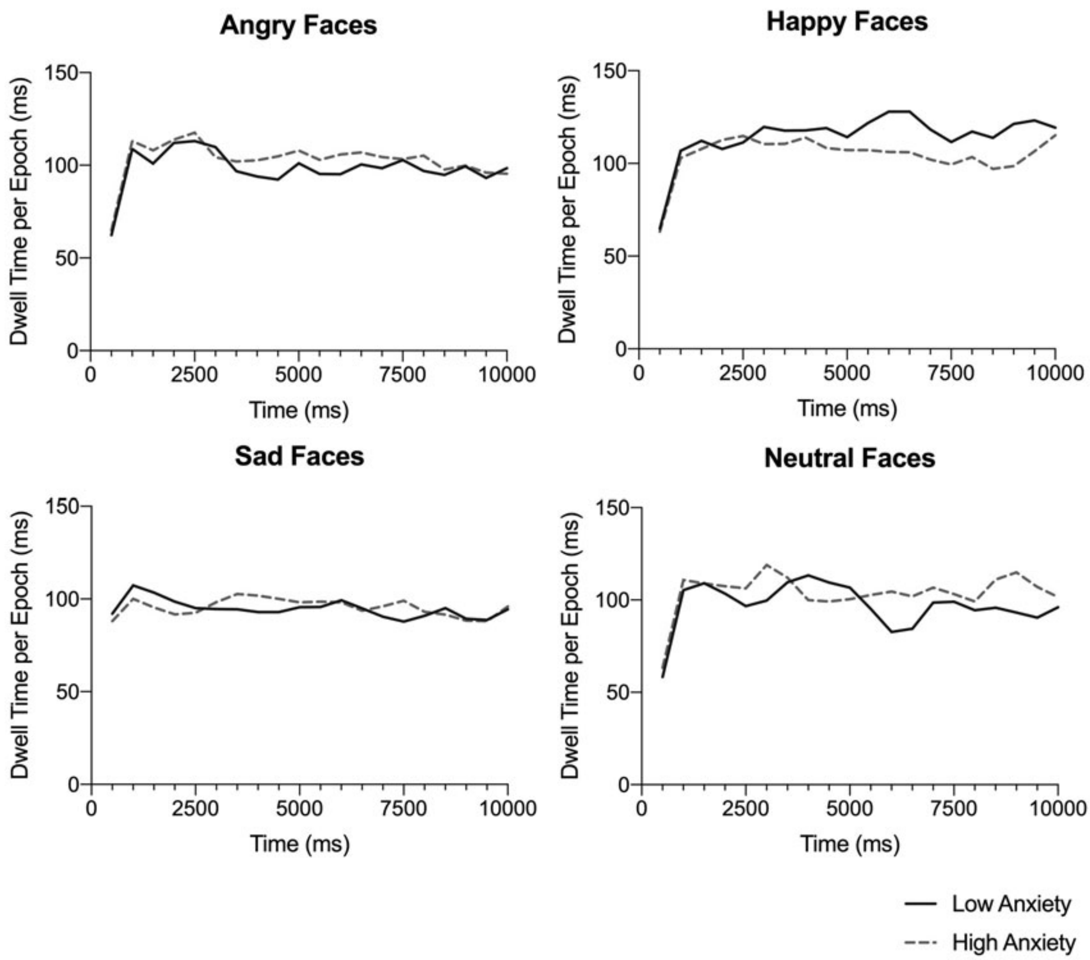

Fig. 2. The mean dwell time by epoch for each emotion face type, separated into participants with low or high self-reported anxiety on the Multidimensional Anxiety Scale for Children. Participants in the low anxiety group ($n = 54$) constituted the bottom quartile of our sample, with MASC total scores ⩽ 27. Participants in the high anxiety group ($n = 53$) constituted the upper quartile of our sample, with MASC total scores ⩾ 49.

anxiety had relatively greater overall dwell time to neutral faces than those with low anxiety, with effects peaking around 3000 ms and then reemerging from 5500 ms through 10 000 ms.

Rerunning the exploratory model employing the binary anxiety diagnosis variable in place of the MASC score produced findings that were generally similar. For neutral faces, main effects for gender ($p < 0.01$) and age ($p < 0.01$) continued to be significant. Age was associated with greater dwell time to neutral faces ($B = 1.41$) and girls ($m = 104.88$ ms, s.e.m. = 1.41) had higher dwell time than boys ($m = 98.63$ ms, s.e.m. = 1.91). Anxiety diagnosis was not a significant predictor of dwell time to angry, happy, or sad faces. However, unlike the dimensional MASC scores, anxiety diagnosis was only marginally associated with dwell time to neutral faces ($p = 0.06$). The effect was in the same direction, with the participants with anxiety disorders attending more on average ($m = 104.11$ ms, s.e.m. = 2.19) to the neutral faces than the non-anxious participants ($m = 99.40$, s.e.m. = 1.21), however, the effect did not reach significance likely due to the loss of power from using a dichotomized rather than a dimensional measure of anxiety and smaller sample.

Discussion

Attentional biases to the threat have repeatedly been linked to pathological anxiety (Armstrong & Olatunji, 2012; Bar-Haim et al., 2007; Dudeney et al., 2015). Yet much of the previous research in this area relied upon experimental designs using reaction time with dot-probe tasks to emotional stimuli presented at a fixed duration (e.g. 500 ms) to make inferences about visual attention as a mechanism for anxiety. However, substantial concerns have been raised about the reliability and validity of using attentional bias dot-probe tasks (e.g. Rodebaugh et al., 2016). To address these concerns, eye-tracking technology has emerged to assess visual attentional biases across continuously measured, longer time windows (e.g. up to 10–15s), as opposed to single ‘snapshot’ dot-probe studies; however, the small eye-tracking literature remains mixed. In the current study, we employed eye-tracking during a passive viewing task with emotionally valenced facial stimuli to examine relationships between attentional processing of threat and both dimensional and categorical indicators of anxiety among a community sample of adolescents.

We did not find a greater likelihood of initial orienting to angry faces, or more rapid orienting to angry faces among participants with anxiety disorders or with higher dimensional ratings of anxiety. In fact, when participants with anxiety disorders oriented first to angry faces, they were significantly slower to do so than controls, although this was a relatively small effect. Given that there was no difference in the proportion of trials on which anxious participants fixated first on angry faces relative

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to other faces, this does not seem to indicate a global avoidance of threatening faces. This finding challenges the notion that anxiety is characterized by more rapid and automatic visual orientation to the potential threat, as was suggested by studies relying on indirect measures of attention and small sample sizes. Overall, the effect sizes for our primary analyses were extremely small across the board, particularly for the dimensional analyses, suggesting that anxiety played little role in determining where and how quickly participants oriented. This is further reinforced by our finding that the speed of orienting to different emotional faces did not differ across the entire sample or when examining our diagnostic groups separately.

Of the few extant eye-tracking studies of attention and pediatric anxiety, others have similarly failed to find evidence for early automatic vigilance for threat linked to anxiety (Gamble & Rapee, 2009; In-Albon et al., 2010; Price et al., 2016). This study is unique in showing that youth with anxiety disorders are *slower* to orient to threatening faces than healthy peers. Interestingly, this finding was not present when examining dimensional anxiety scores as a predictor, indicating slower threat orientation may characterize youth with clinically significant levels of anxiety, according to DSM-IV GAD and SAD diagnoses. Our findings contrast with those of Shechner et al. (2013) who found that anxious youth showed greater PFF and shorter TFF on angry faces compared to healthy peers. Although both studies employed 10-s passive viewing trials featuring emotional faces from the NimStim set, the Shechner study presented stimuli as face pairs, whereas the current study used four concurrent pictures. Employing face pairs may bias studies to evidence of initial vigilance, given that participants are restricted in orienting options, while the added perceptual complexity of larger arrays of faces may mitigate this effect (Armstrong & Olatunji, 2012; Derakshan & Koster, 2010; Richards, Benson, Donnelly, & Hadwin, 2014). We elected to use a quadrant grid design as it allowed us to examine competition for attention across multiple emotional faces simultaneously, but without using an overwhelming large array of faces. A similar quadrant design was used in a previous study examining attentional bias using eye-tracking among young adults (Beevers, Ellis, Wells, & McGeary, 2010). We consider this a strength of our design, however, it clearly limits its comparability with previous experiments that employed face pairs. Overall, it appears that links between attention to threat and anxiety may thus be subtle and highly dependent on experimental task dimensions (Mogg & Bradley, 2018).

Our examination of dwell time to angry faces also failed to find a main effect of anxiety or interaction of anxiety and time using either dimensional or categorical measures of anxiety. Interestingly, we found the main effect of dimensional anxiety on dwell time to *neutral* faces, as well as an interaction between anxiety and time, indicating anxiety severity was associated with greater attention to neutral faces, especially during later portions of the trial during which attention may be more volitional. The effect was similar using the categorical operationalization of anxiety, although the main effect of anxiety diagnosis was only marginally significant. Anxious participants may have fixated preferentially on neutral faces in order to avoid emotionally-valenced faces, consistent with the avoidance hypothesis. However, previous research suggests that neutral faces may be experienced as threatening to those with anxiety disorders and may command more attentional processing (Filkowski & Haas, 2017). In many eye-tracking studies and particularly in studies using the dot-probe task, neutral faces are used as the baseline comparator for attention to other emotion face types. As others have suggested, this may be inappropriate if certain clinical groups do not assess neutral faces as 'neutral' (Filkowski & Haas, 2017). Neuroimaging studies of adults have found that those with anxiety disorders engage the amygdala and other regions involved in evaluating emotional salience differently than controls when presented with neutral faces (Cooney, Atlas, Joormann, Eugène, & Gotlib, 2006; Gentili et al., 2008; Pillay, Rogowska, Gruber, Simpson, & Yurgelun-Todd, 2007). From this perspective, our findings are more consistent with the maintenance hypothesis (i.e. neutral faces are threatening stimuli from which anxious teens have difficulty disengaging). Future studies are needed to employ designs in which attention to neutral faces can be assessed independently from other emotional faces.

This study has several limitations. First, while eye-tracking provides a more direct measure of visual attention than reaction time tasks, attentional shifts can occur independent of eye movements (i.e. covert attentional shifts; Moore, Armstrong, and Fallah, 2003) and thus we cannot assume to have fully captured all aspects of attention during this experiment. Second, the face stimuli employed in our task featured young adults and thus may have been less socially relevant than stimuli featuring same-age adolescent peers. Third, our task featured static face pictures. While this design is highly controlled and allows for relatively straightforward analyses, it may not reflect how youth process dynamic, varied, and often subtle emotional stimuli they encounter in their daily lives. In future studies, we hope to design and employ more naturalistic stimuli, to examine attention with and without experimentally-induced anxiety, and to use improved eye-tracking methodology to examine attention in a more externally valid way (Fu & Pérez-Edgar, 2019).

Overall, our findings call into question the relationship between attentional biases to threatening faces and anxiety among adolescents. With a relatively large and diverse community sample, we examined the question both categorically and dimensionally, and employed both technology and a design that allowed us to examine attention with a degree of granularity not seen in most experiments. Previous links between anxiety and threat biases had arisen primarily from the methodologically flawed dot-probe literature, and an inconsistent, small eye-tracking literature, thus it will be critical to continue to investigate this issue employing eye-tracking and varied experimental designs. Understanding if, and under what circumstances, attentional biases to threat contribute to pediatric anxiety is of clinical significance given ongoing efforts to develop interventions to treat anxiety by remediating attentional biases to threat (e.g. Pettit et al., 2019).

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Conflict of interest. None.

Ethical standards. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and the Helsinki Declaration of 1975, as revised in 2008.

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