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Psychometric properties of threat-related attentional bias in young children using eye-tracking

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Abstract

Anxiety is one of the most common forms of child psychopathology associated with persistent impairment across the lifespan. Therefore, investigating mechanisms that underlie anxiety in early childhood may improve prevention and intervention efforts. Researchers have linked selective attention toward threat (i.e., attentional bias to threat) with the development of anxiety. However, previous work on attentional bias has used less reliable, reaction time (RT)-based measures of attention. Additionally, few studies have used eye-tracking to measure attentional bias in *young* children. In the present study, we investigated the psychometric properties of an eye-tracking measure of attentional bias in a sample of young children between 6- and 9-years-old and explored if trait and clinical anxiety were related to attentional biases to threat. Results showed good psychometric properties for threat and neutral attentional biases, comparable to those found in adult eye-tracking studies. Temperamental and clinical anxiety did not significantly relate to threat/neutral dwell time and attentional biases. The significance of these null findings was discussed in relation to existing developmental theories of attentional biases. Future studies should explore if temperamental or clinical anxiety prospectively predict threat attentional bias and the onset of anxiety in older children using a longitudinal design.

KEYWORDS

anxiety, attentional bias, development, eye-tracking, psychometrics

1 | INTRODUCTION

Approximately 5%–17% of children experience some form of anxiety disorder (see Cartwright-Hatton et al., 2006, for a review; Costello et al., 2005; Ghandour et al., 2019). Childhood anxiety disorders are associated with tremendous societal costs (Bodden et al., 2008; Kessler et al., 1995; Spence et al., 1999) and often result in chronic impairment (Beesdo et al., 2009; Beesdo, et al., 2010; Kessler et al., 2012; Last et al., 1996; Pine et al., 1998). Investigation into correlates of anxiety early in development is crucial for understanding the etiopathogenesis of clinical anxiety and improving prevention and intervention efforts.

In the context of our evolutionary history, selective attention toward threat-related information has enabled humans to efficiently detect danger. Trait anxiety is thought to lower the threshold level for threat-related stimulus detection. Cognitive theories of anxiety posit that highly anxious individuals are characterized by cognitive biases, such that these individuals preferentially allocate attention to fear- and threat-related stimuli (Beck & Clark, 1997; Eysenck, 2014; Mogg & Bradley, 1998). Indeed, individuals with clinical anxiety as well as healthy individuals with high trait anxiety have particularly strong emotional biases in attention, especially to threat-related material (Bar-Haim et al., 2007; Mogg & Bradley, 1998). This effect of attentional capture persists even when participants were not consciously aware of the threat-related distractors (Mogg & Bradley, 1998).

Several researchers have also conducted longitudinal studies exploring the role of threat attentional bias in the emergence of

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anxiety disorders. It has been suggested that attentional bias toward threat may act as a moderator between fearful temperament and later anxiety and social withdrawal (Morales et al., 2015; Pérez-Edgar et al., 2010; White et al., 2017). Furthermore, reviews by Van Bockstaele et al. (2014) and Morales et al. (2016) have suggested that there may be bidirectional relationships between threat-related attentional bias and anxiety, such that threat-biased attention and anxiety may amplify each other. Indeed, despite strong evidence of a relationship between anxiety and attention, the exact mechanism(s) whereby attention to threat may lead to anxiety (or vice versa) remain unclear (Burris et al., 2019).

Recent meta-analyses supported the general finding that anxiety is associated with selective attention toward threatening stimuli in both adults and children, $d = 0.21$ to 0.45 (Bar-Haim et al., 2007; Dudeney et al., 2015; Lisk et al., 2020). However, there are some mixed findings in the developmental literature: some studies have shown that children with anxiety are more vigilant toward threat (Dalgleish et al., 2003; Vasey et al., 1995; Waters et al., 2010), others show avoidance of threat-related information (Monk et al., 2006), or no difference in attentional bias between healthy and anxious children (Benoit et al., 2007; Britton et al., 2012; Hadwin et al., 2009). These mixed results may be attributed to inconsistencies in measurement methods of attentional bias.

Previous work on threat-related attention bias has primarily relied on reaction time (RT) measures of attention, such as the emotional Stroop task, emotional spatial cueing task, and the dot-probe. While some studies have found attentional biases in anxious individuals, RT-based measures of attention may not be psychometrically reliable, and researchers have called into question the validity of traditional RT measures of attentional bias (Armstrong & Olatunji, 2012; Rodebaugh et al., 2016; Schmukle, 2005; Staugaard, 2009; Waechter et al., 2014). Traditional RT measures are sensitive to confounding effects of response execution, have poor psychometric properties (Cooper et al., 2011; Schmukle, 2005; Staugaard, 2009), and are unable to adequately describe dynamic processes of attention due to their "snapshot" nature (Armstrong & Olatunji, 2012). More recently, eye-tracking technology has begun to be utilized *to directly measure continuous, overt eye movements*, and address methodological issues of traditional RT tasks (Waechter et al., 2014). Thus, eye-tracking may be viewed as a more direct measure of attention (compared to RT measures) and may have better overall psychometric properties.

A review by Field and Lester (2010) put forth a number of developmental models of attention bias to threat and individual differences in anxiety or fearfulness. One model, the moderation model, proposed that biases toward threat are present early in development, but change over time as a function of individual differences such as fearfulness. In other words, this model predicted that in young children, we should observe a main effect of threat, such that all children display an attention bias to threat versus neutral stimuli; however, individual differences in fearfulness will begin to relate to attention bias to threat later in development. Kindt and Van Den Hout (2001) suggested that children who are not fearful may learn to inhibit automatic processing of potential threat over time and therefore have a less attentional bias to threat as they grow older (Field, 2006a, 2006b; LoBue, 2010); in contrast, fearful children fail to learn this ability and remain biased toward threat-related stimuli (Kindt et al., 2000). In addition to the moderation model, Field and Lester (2010) also proposed potential alternative models, such as the integral bias model (i.e., attentional biases to threat do not change with child development) and the acquisition model, wherein attentional biases are not present in young children but emerge with cognitive, social, or emotional development.

While attentional bias eye-tracking studies in children are scant, there are a few publications of particular relevance to our study. Consistent with the moderation model, Dodd et al. (2015) did not find any between-group differences in threat bias in anxious versus non-anxious young children between the ages of 3- and 4-years-old. Work by Fu et al. (2019) did not find any significant difference in stationary eye-tracking measures of attention between behaviorally inhibited (BI) and non-BI 5- to 7-year-old children. Moreover, Shechner et al. (2013) found that anxious youth between 8- and 17-years-old had greater attentional bias to threat-related stimuli as compared to their non-anxious counterparts. Taken together, the data available appear to support the moderation model (i.e., all children have threat-related attentional biases, and individual differences in fearfulness begin to relate to threat attentional biases in older children) proposed by Field and Lester (2010).

In the present study, we wished to establish the psychometric properties of eye-tracking measures of attentional bias to threat-relevant stimuli in *young* children. In light of the fact that anxiety often begins early in life, it is imperative to characterize *early* developmental trajectories. Intervention for anxiety disorders may be more effective early in development (Mancebo et al., 2014), and there is some evidence showing attentional biases can be trained and may reduce anxiety (Bar-Haim, 2010; Bar-Haim et al., 2011; De Voogd et al., 2014; MacLeod & Clarke, 2015; Price et al., 2016). Although much work on attentional bias modification training has been conducted in adults, results from the handful of studies in children appear to be promising (Chang et al., 2019; Lowther & Newman, 2014). Given the potential implications for future work on attentional bias training in children, it is imperative to examine whether it is possible to reliably measure attention bias in young children. Previous work in adult populations has found good reliabilities for eye-tracking, ranging from $\alpha = 0.79$ to 0.94 (Skinner et al., 2018; Waechter et al., 2014). Recent papers have published eye-tracking data on attentional biases to threat in young children (Dodd et al., 2015; Fu et al., 2019; Linetzky et al., 2019; Shechner et al., 2013). However, no previous study, to our knowledge, has examined the psychometric properties of eye-tracking in young children. In the current study, we investigated the psychometric properties of an eye-tracking measure of threat-related attention bias in children between the ages of 6- and 9-years-old.

Additionally, we examined whether individual differences in anxiety relate to threat-related attentional biases in young children and measured anxiety symptom dimensions using multiple parent-reports, temperamental fear and shyness, as well as child clinical anxiety diagnoses based on clinical interviews with parents. We also tested potential interactions between age and threat-related attention bias predicting anxiety given the developmental models discussed above. Previous work suggested that attention bias measured using eye-tracking is psychometrically reliable in adults (Skinner et al., 2018; Waechter et al., 2014); therefore, we predicted that eye-tracking in young children would be characterized by good psychometric properties. Moreover, based on previous work linking threat-related attention bias to anxiety, we hypothesized that both dimensional and categorical measures of anxiety would relate to anxiety in young children.

2 | METHOD

2.1 | Participants

The study consisted of 70 children (46.3% female) between the ages of 6- and 9-years-old ($M = 6.83$, $SD = 0.80$) who were recruited from the community in Tallahassee, Florida. Out of the full sample, 69 children had eye-tracking data (1 child was unable to sit still during the eye-tracking task).

Participants with severe neurodevelopmental disorders were excluded from the study. Overall, 4.3% of parents reported their child as Asian, 20% as Black/African American, 70% as White/Caucasian, and 5.7% as Other. Regarding parent education, 4.3% reported "high school diploma or equivalent (GED)," 25.7% reported "some college/2-year degree," 27.1% reported "college degree," and 41.4% reported "graduate degree," and 1.4% did not report on the level of education. Additionally, for estimated annual family income, 2.9% reported making less than $10,000 per year, 7.1% reported making $10,000 to $25,000 per year, 10% reported making $25,000 to $40,000 per year, 34.3% reported making $40,000 to $75,000 per year, 44.3% reported making more than $75,000 per year, and 1.4% did not report on annual family income.

2.2 | Measures

2.2.1 | Eye Tracking Task and Measure

Eye-tracking data were recorded using a fixed EyeLink 1000 Plus eye-tracker with monocular recording at 500Hz (SR Research, US). Gaze data for this equipment are typically accurate to 0.25-0.50° (SR Research, US). Operating distance to the eye-tracking monitor was 550–600 mm. Stimuli were presented on a Dell U2417H monitor with a screen resolution of 1920 × 1,080 pixels.

Participants completed a validated free viewing task (see Figure 1; Lazarov et al., 2016, 2017) as eye gaze data were collected using an EyeLink 1000 Plus (SR Research, US). The task was preceded by a 13-point eye-tracking calibration followed by a 13-point validation. The calibration procedure was repeated if visual deviation was above 1° on the *X* or *Y* axis. Calibration parameters were to be achieved before proceeding with the task. Each trial began with a fixation cross in the middle of the screen, which the participant had to fixate on for 1,000 ms to invoke the next display. Then, a 4 × 4 matrix (16 different faces) was displayed on the screen for 6,000 ms with eight faces displaying disgust expressions (threat stimuli), and another eight faces displaying neutral expressions (neutral stimuli). Disgust facial expressions have been successfully used as threat stimuli in previous studies (Costafreda et al., 2008), including in studies involving anxious children (Benoit et al., 2007; Shechner et al., 2014). Moreover, it has been shown that anxious individuals had larger anterior cingulate cortex (ACC) and amygdala activation in response to disgust facial expressions as compared to other facial expressions (Amir et al., 2005). The matrix consisted of eight male and eight female adult faces, with the four inner faces always displaying two disgusted and two neutral faces. Face stimuli were obtained from the Karolinska Directed Emotional Faces set (Lundqvist et al., 1998). Participants were instructed to look freely at each matrix until the matrices disappeared. The free viewing task consisted of 30 randomized trials with 2,000 ms intertrial intervals.

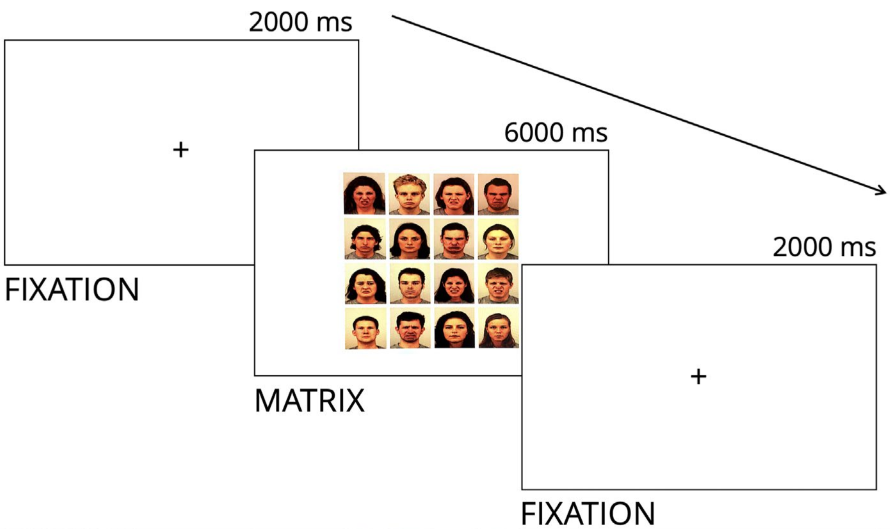

FIGURE 1 Trial sequence of the free-viewing task

Eye-tracking data were processed using EyeLink Data Viewer Version 3.1 (SR Research, US). Gaze fixations were defined as any period that is not a blink or saccade and lasts for at least 100 ms (SR Research, US). We defined two types of AOI for each matrix—one for the eight angry facial expressions (threat AOI) and one for the eight neutral facial expressions (neutral AOI). Duration of time (ms) spent looking at each type of stimuli was recorded, and the proportion of time spent looking at threatening stimuli out of the total duration spent on each matrix was calculated for each matrix. Then, the overall proportion dwell time to threat stimuli was determined by averaging the proportion of time spent looking at threatening stimuli for each matrix across all 30 trials according to methods used in Linetzky et al. (2019). The same calculations were repeated to obtain the overall proportion dwell time to neutral stimuli (i.e., raw scores of dwell time). Given that raw scores may encompass affect-irrelevant variables, such as individual differences in attentiveness to the task, we created two types of difference scores to calculate attentional bias scores: (a) subtraction-based (i.e., threat minus neutral proportion dwell time) and (b) regression-based (i.e., saving the unstandardized residuals from a regression wherein neutral proportion dwell time was entered predicting threat proportion dwell time).[1] Difference scores allow us to control for these third variables. Additionally, we created two types of difference scores to isolate the variance associated with attentional bias toward threat/neutral stimuli, given that residualized difference scores may offer several benefits over subtraction-based difference scores (Meyer et al., 2017) and produce difference measures for threat and neutral stimuli that are unique and independent of each other. Including both measures of difference scores allows us to determine if potential relationships between anxiety and threat attentional bias may depend on neutral attentional bias scores.

2.2.2 | Parent-report questionnaires

Anxiety symptoms were assessed with the Screen for Child Anxiety-Related Emotional Disorders (SCARED; Birmaher et al., 1997, 1999) and Children's Behavior Questionnaire (CBQ; Rothbart et al., 2001).

The SCARED is a 41-item questionnaire assessing broad symptoms of anxiety in children, such as panic, general anxiety, separation anxiety, social phobia, and school phobia. Items were rated ranging from 0 (*not true or hardly ever true*) to 2 (*true or often true*). We obtained information from parents in this study. Examples of items from the questionnaire included, "When my child feels frightened, it is hard for him/her to breathe" and "My child has nightmares about something bad happening to his/her parents." Higher scores on the SCARED represented increased child anxiety. Total parent-reported SCARED scores obtained excellent internal reliability, $\alpha = 0.90$.

We assessed children's temperamental characteristics of fearfulness and shyness by administrating the CBQ (Rothbart et al., 2001) to parents. The CBQ is a 195-item parent-report assessment of temperament in early to middle childhood (i.e., ages 3–7 years) and evaluates 15 dimensions of temperament: activity level, anger/frustration, approach, attentional focusing, discomfort, falling reactivity and soothability, fear, high-intensity pleasure, impulsivity, inhibitory control, low-intensity pleasure, perceptual sensitivity, sadness, shyness, and smiling and laughter. Response options ranged from 1 (*extremely untrue of your child*) to 7 (*extremely true of your child*). CBQ subscales of interest included Fear and Shyness, and these subscales included 13 items each. Examples of items on the Fear subscale include, "My child is afraid of the dark" and "My child gets nervous about going to the dentist." The Shyness subscale comprises items such as "Sometimes prefers to watch rather than join other children playing" and "Gets embarrassed when strangers pay a lot of attention to her/him." Higher scores on a temperamental dimension indicated more endorsement of that temperamental trait. All CBQ subscales (i.e., fearfulness and shyness) obtained excellent internal reliability, similar to Rothbart et al. (2001), Cronbach's $\alpha = 0.80$-0.90.

2.2.3 | Clinical Interviewing

The Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children: Present and Lifetime Version (K-SADS-PL; Kaufman et al., 1997), modified for DSM-IV, was administered by trained interviewers who were trained and supervised by a PhD level clinician. The K-SADS-PL was administered to parents to assess a wide range of past and current psychopathology in children. The K-SADS-PL has demonstrated excellent test–retest reliability and inter-rater agreement (0.77–1.00 and 93%–100%, respectively; Kaufman et al., 1997). All interviews were recorded, and diagnoses were reviewed in case conferences held by the PhD level clinical psychologist.

2.2.4 | Procedure

Upon the family's arrival in the laboratory, a research assistant briefly explained the experiment and obtained informed consent from the parent and assent from the children. Then, the children completed the attention bias task as eye-tracking data were collected. The children were instructed to look freely at the matrices until they disappeared. The parents completed the self-report measures and clinical interviewing during this time. The full visit to the laboratory lasted for approximately 3 to 4 hr. Data were collected as part of a larger study.

2.2.5 | Data Analytic Approach

Statistical analyses were conducted using SPSS (Version 23.0) general linear model software. A repeated-measures ANOVA was conducted to examine dwell time by stimuli type (threat versus neutral). Subtraction-based and regression-based difference scores were calculated to obtain attentional bias scores for each condition. We examined the psychometric properties of the attentional bias task and measures of anxiety using Spearman-Brown corrected split-half reliabilities (using odd-even trials) and Cronbach's alpha.

The analyses described below were conducted with proportion dwell time scores as well as the attentional bias difference scores that obtained the best internal reliability. Associations between all study variables were examined using Pearson's *r* and one-way analyses of variance (ANOVA), and chi-squared test. A nonparametric bootstrapping approach (MacKinnon et al., 2004) was used to test if child age moderated the relationship between anxiety and threat attentional bias. All moderation analyses were conducted using the PROCESS Version 3.3 SPSS macro (Preacher & Hayes, 2004) model 1. PROCESS estimates regions of significance using the Johnson-Neyman technique. Variables were mean centered to minimize multicollinearity (Aiken et al., 1991).

3 | RESULTS

A repeated-measures ANOVA revealed that children spent more time looking at threat stimuli ($M = 0.47$, $SD = 0.05$) compared to neutral stimuli ($M = 0.41$, $SD = 0.05$), $F(1, 68) = 33.47$, $p < .001$, $\eta^2 p = .33$. Threat and neutral proportion dwell time were significantly moderately negatively correlated, $r = -.30$, $p = .01$. To calculate attentional bias and control for confounding variables such as individual differences in task compliance, two types of difference scores were created: (a) subtraction-based (i.e., threat minus neutral proportion dwell time) and (b) regression-based (i.e., saving the unstandardized residuals from a regression, threat proportion dwell time was regressed on neutral proportion dwell time). Means, standard deviations, and Pearson correlations for study variables are presented in Table 1.

Child age was not significantly related to threat dwell time, neutral dwell time, or attentional bias scores.[2] Regarding sex differences, females spent more time looking at neutral stimuli than did males and also had higher neutral attentional bias scores than did males. However, there were no sex differences in threat dwell time or threat attentional bias scores.[2] Statistical information for the one-way ANOVAs as well as means and standard deviations by sex are displayed in Table 2.

3.1 | Psychometric properties

Spearman-Brown corrected split-half reliabilities of proportion dwell time on neutral and threat faces were acceptable according to Skinner et al. (2018), $r = .65$ and $r = .60$, respectively. We also calculated Spearman-Brown corrected split-half reliabilities for raw dwell time (ms) on neutral and threat faces. Results showed that reliabilities were acceptable, $r = .71$ and $r = .69$, respectively.

Spearman–Brown corrected split-half reliabilities of subtraction-based neutral and threat attentional bias scores were acceptable, both *r*s = .49. Spearman-Brown corrected split-half reliabilities of regression-based neutral and threat attentional bias scores were good, $r = .81$ and $r = .77$, respectively. Given that regression-based difference scores were more internally reliable than subtraction-based difference scores, subsequent analyses were conducted using regression-based scores.

Additionally, we used a median split to group children into younger and older age groups to examine if psychometric properties of the eye-tracking task differed based on child age. Spearman–Brown corrected split-half reliabilities for proportion dwell time on neutral faces in younger children were better than that in older children, $r = .73$ and $r = .46$, respectively. We obtained similar Spearman–Brown corrected split-half reliabilities for proportion dwell time on threat faces in younger and older children, both *r*s = .60. The pattern of results was similar for residualized-based scores of attentional biases. Regarding psychometric properties of residualized neutral attentional bias scores, younger children, $r = .83$, had better

TABLE 1 Correlations and descriptive statistics for key study variables

	1	2	3	4	5	6	7	8	*M*	*SD*
1. Age	1								6.83	0.80
2. CBQ Fear	−.17	1							3.67	1.08
3. CBQ Shyness	.02	.38**	1						3.28	1.15
4. SCARED Total	−.07	.49**	.49**	1					11.81	9.01
5. Threat Dwell Time	−.09	−.06	−.04	.05	1				0.47	0.05
6. Neutral Dwell Time	.12	−.19	.04	.13	−.30*	1			0.41	0.06
7. Threat Attentional Bias	−.06	−.12	−.03	.09	.95**	0	1		0	0.05
8. Neutral Attentional Bias	.10	−.22†	.03	.16	0	.95**	.30*	1	0	0.06

Regression-based difference scores are labeled Threat and Neutral Attentional Bias.

Abbreviations: CBQ = Child Behavior Questionnaire; SCARED = Screen for Child Anxiety Related Emotional Disorders.

†$p < .10$;

*$p < .05$;

**$p < .01$.

TABLE 2 Means and standard deviations of key variables by gender

Measures	Male ($N = 36$)		Female ($N = 31$)			
	M	*SD*	*M*	*SD*	*F*	η^2
Threat dwell time	0.48	0.05	0.46	0.05	0.99	.02
Neutral dwell time	0.39	0.06	0.43	0.05	7.83**	.11
Threat attentional bias	0.00	0.05	−0.00	0.05	0.04	.00
Neutral attentional bias	−0.02	0.06	0.02	0.05	6.67*	.09
CBQ						
Fear	3.72	1.15	3.56	1.03	0.32	.00
Shyness	3.23	1.11	3.48	1.17	0.78	.01
SCARED						
Total	11.69	8.84	12.35	9.59	0.09	.00
Panic	0.86	1.48	0.48	0.89	1.54	.02
Generalized anxiety disorder	3.42	3.41	3.23	2.94	0.06	.00
Separation anxiety	3.58	3.23	3.58	3.03	0.00	.00
Social anxiety disorder	3.42	3.11	4.61	3.94	1.93	.03
School avoidance	0.42	0.73	0.45	0.96	0.03	.00

Regression-based difference scores are labeled Threat and Neutral Attentional Bias.
Abbreviations: CBQ = Child Behavior Questionnaire; SCARED = Screen for Child Anxiety Related Emotional Disorders.
*$p < .05$;
**$p < .01$.

TABLE 3 Means and standard deviations of key variables by anxiety diagnostic status

Measures	Healthy ($N = 51$)		Anxious ($N = 19$)			
	M	*SD*	*M*	*SD*	*F*	η^2
Threat dwell time	0.47	0.05	0.46	0.06	0.33	.01
Neutral dwell time	0.41	0.05	0.41	0.07	0.04	.00
Threat attentional bias	0.00	0.05	−0.01	0.06	0.44	.01
Neutral attentional bias	0.00	0.05	−0.00	0.07	0.14	.00
CBQ						
Fear	3.35	0.92	4.50	1.06	20.05**	.23
Shyness	3.04	1.11	3.92	1.02	8.85**	.12
SCARED						
Total	9.20	7.32	18.84	9.54	20.30**	.23
Panic	0.59	1.13	1.00	1.45	1.56	.02
Generalized anxiety disorder	2.57	2.38	5.16	4.10	10.79**	.14
Separation anxiety	2.80	2.64	5.68	3.32	14.30**	.17
Social anxiety disorder	2.86	2.86	6.32	4.10	15.85**	.19
School avoidance	0.37	0.75	0.68	1.06	1.90	.03

Regression-based difference scores are labeled Threat and Neutral Attentional Bias.
Abbreviations: CBQ = Child Behavior Questionnaire; SCARED = Screen for Child Anxiety Related Emotional Disorders.
*$p < .05$,
**$p < .01$.

Spearman-Brown corrected split-half reliabilities as compared to older children, $r = .72$. Residualized threat attentional bias scores obtained similar Spearman–Brown corrected split-half reliabilities in younger, $r = .78$, and older children, $r = .77$.

3.2 | Parent-reported Child Anxiety

Overall, as expected, parent-reported measures of child anxiety (i.e., CBQ Fear, CBQ Shyness, SCARED) were significantly related to each

TABLE 4 Child age × Threat attentional bias (AB) predicting anxiety

Outcome variable	Child Age			Threat AB			Age X Threat AB				
	β	*SE*	*t*	*β*	*SE*	*t*	*β*	*SE*	*t*	R^2	*F*
Model 1: CBQ Fear	−0.26	0.16	−1.59	−3.18	2.69	−1.18	5.44	3.50	1.56	.08	1.90
Model 2: CBQ Shyness	−0.02	0.18	−0.13	−0.64	2.92	−0.22	1.40	3.79	0.71	.003	0.06
Model 3: Total SCARED	−0.86	1.41	−0.61	16.67	23.25	0.72	2.33	30.22	0.08	.01	0.32
Model 4: K-SADS Diagnostic Status	0.10	0.34	0.31	−3.74	5.56	−0.67	4.00	7.21	0.55	.02[a]	–

Regression-based difference score is labeled Threat AB.

Abbreviations: CBQ = Child Behavior Questionnaire; SCARED = Screen for Child Anxiety Related Emotional Disorders; K-SADS = Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children: Present and Lifetime Version;

[a]Nagelkerke's R^2 is reported.

other (Table 1). None of the parent-reported SCARED total, SCARED subscale scores, CBQ fearfulness, or CBQ shyness significantly differed by sex (Table 2).

Overall, 19 children had at least one or more current threshold anxiety disorder from interviewing parents with the K-SADS-PL. Of the 19 children, 3 had separation anxiety disorder, 11 had simple phobia, 3 had social phobia, 3 had generalized anxiety disorder, 2 had obsessive-compulsive disorder, and 3 had anxiety not otherwise specified (NOS). Child sex and anxiety diagnostic status were not significantly related, χ^2 (1, $N = 67$) = 1.44, $p = .23$. Moreover, child age did not differ significantly based on anxiety diagnostic status, F(1, 69) = 0.18, $p = .68$. Dimensional symptoms of anxiety (i.e., SCARED Total, CBQ Fear and Shyness) were significantly elevated in children with clinical levels of anxiety, all $ps < .01$ (Table 3). Moreover, all subscale scores on the parent-reported SCARED were also significantly elevated in children with clinical anxiety, with the exception of the Panic and School Avoidance subscales. Statistical information for the one-way ANOVAs, as well as means and standard deviations by anxiety diagnostic status, are reported in Table 3.[2]

3.3 | Age, attentional bias to threat, and child anxiety

We conducted one-way ANOVAs to determine if the proportion of dwell time or attentional bias scores differed by anxiety diagnostic status. Proportion of dwell time and attentional bias scores did not significantly differ based on anxiety diagnostic status, all $ps > .10$ (Table 3).[2]

Finally, we tested four models examining the interactions between child age and threat attentional bias predicting different measures of anxiety using a nonparametric bootstrapping method. In other words, predictors remained the same across all models, while the outcome variable was changed (i.e., SCARED Total, CBQ Fear, CBQ Shyness, K-SADS-PL). All main and interaction effects were non-significant, $ps > .05$ (Table 4). [2,3]

4 | DISCUSSION

As expected and consistent with previous findings, children generally spent more time looking at threat stimuli than neutral stimuli (Creswell et al., 2008; Field & Lester, 2010; Gamble & Rapee, 2010; Mogg & Bradley, 2006; Schofield et al., 2012). Of note, this study serves as a novel extension of the developmental literature on attentional bias. Thus far, only a handful of studies have used eye-tracking technology to measure attentional bias to threat in young children (Dodd et al., 2015; Fu et al., 2019; Linetzky et al., 2019; Shechner et al., 2013).

Few studies in the literature have investigated the psychometric properties of eye movement indices to threat stimuli (Armstrong & Olatunji, 2012; Skinner et al., 2018; Waechter et al., 2014). To our knowledge, there are no studies in the literature examining the psychometric properties of attentional bias using eye-tracking in *young* children. In the present study, we found that neutral and threat proportion dwell times, as well as residualized attentional bias scores, obtained split-half reliabilities similar to previous research in adults and older children (Linetzky et al., 2019; Skinner et al., 2018; Waechter et al., 2014). This suggests that it is possible to obtain a reliable measure of attentional bias in young children. Moreover, traditional RT-based attentional bias tasks have been shown to obtain non-significant and unacceptably low split-half reliabilities in children ($rs = -.24$ to $.33$; Brown et al., 2014) as well as adults ($rs = .10$ to $.44$; Waechter & Stolz, 2015). This supports the notion that eye-tracking measures of attentional bias may have better overall psychometric properties as compared to traditional RT measures of attentional bias for children and adults (Armstrong & Olatunji, 2012; Waechter et al., 2014). Additionally, we found that neutral stimuli dwell times in younger children obtained better psychometric properties than that in older children. This increased variability in older children may be interpreted as a proxy for developmental change that begins to arise in this age range (Koolschijn et al., 2011). Indeed, some work has begun to suggest that puberty may impact correlates of anxiety (e.g., performance monitoring, startle habituation, and brain regions for cognitive control; Gorday & Meyer, 2018; Koolschijn et al., 2011). It is possible this increased variability in older children may be fueled by individual differences in the onset of pubertal changes.

Results also suggested that sex was a significant predictor of neutral proportion dwell time and neutral attentional bias, such that girls spent more time looking at neutral stimuli than did boys. It is possible that girls were more compliant with the task, and therefore spent more time looking at the screen as compared to boys. It is also possible that girls were characterized by increased conscientiousness (Lay et al., 1998), which led to less off-task behavior (i.e., looking off the screen). Considering that this relationship was not hypothesized a priori, future work is needed to further explore potential sex differences in attention to neutral stimuli in young children.

As expected, all anxiety measures obtained excellent psychometric properties and were significantly positively related to one another. Child demographic variables of age and sex were not related to any anxiety measures. None of the anxiety measures (i.e., SCARED, CBQ Fear, CBQ Shyness) were significantly related to threat or neutral dwell time or attentional biases; moreover, we did not find any significant interactions between child age and threat attentional bias predicting anxiety. These null results should be considered in the context of developmental models of attentional bias.

Of note, our study has two important findings: (a) attentional bias to threat exists as the main effect in 6- to 9-year-olds; and (b) attention bias to threat does not relate to individual differences in anxious traits in this age range. In other words, consistent with Field and Lester's (2010) moderation model, threat attentional bias does not appear to relate to individual variation in anxiety in this young age range. Results from the current study are a first step in understanding developmental trajectories of attention bias, insofar as our findings suggest children under the age of 9-years-old display attention biases to threat, but that attention to threat does not relate to individual differences in anxiety. Indeed, Kindt et al. (2000) found biases to threat in all children aged 8, and several studies have shown that attentional biases are present in all children, beginning very early in development (LoBue, 2010; LoBue & DeLoache, 2008; Rakison & Derringer, 2008). Field and Lester (2010)'s moderation model suggests that relationships between threat bias and anxiety should begin to emerge around 10 years of age. The Kindt et al. (2000) study found that biases to threat decreased as age increased in non-phobic children but remained consistent across age in phobic children—this differentiation in biases between phobic and non-phobic children arose at around 10-years-old. Considering that the agerange of the current sample spanned 6- to 9-years-old, our findings partially support the Field and Lester (2010) moderation model. Longitudinal data are needed to confirm this pattern of results (i.e., that threat-bias will begin to relate to anxiety as these children age). Given that only 30–40% of the variance in attentional biases to threat is heritable (Zavos et al., 2010), future studies should investigate if trait anxiety in young children prospectively predicts threat attentional bias and the later development of anxiety disorders using a longitudinal study. It is also possible that attentional biases to threat in young children have not yet resulted in observable trait anxiety that could be reported by parents—this underlying risk factor may develop into anxiety or fearfulness over time. Future studies may examine this possibility through a longitudinal design. Alternatively, replicating this study in a sample of older children cross-sectionally may elucidate novel relationships between trait anxiety and threat-related attentional bias. Given that the Field and Lester (2010) moderation model suggests group differences may begin to arise around 10-years-old, future work may attempt to include a broader age range that encompasses this critical developmental period (e.g., 8- to 15-years-old).

We would also like to highlight several key differences between the passive free-viewing task used in this study as compared to other tasks used in the attentional bias literature. First, this free-viewing task uses faces as the main stimuli that participants attend to; faces are often irrelevant to the primary goal during traditional attentional bias tasks such as the dot-probe. Second, this free-viewing task utilizes a display matrix with multiple threat faces, while traditional attentional bias tasks use one threat face in an array of neutral faces. Furthermore, Posner's model of attention involves three core areas of functioning: (a) the alerting network, involved in obtaining and maintaining an alert state; (b) the orienting network, related to the selection of sensory events; and (c) the executive attention system, tasked with resolving conflict among response tendencies (Posner et al., 2012). Prior works on attentional bias using RT-based tasks, such as the dot-probe, capture more transient forms of attention allocation. Our study, on the other hand, utilizes a passive viewing eye-tracking task, which taps into sustained components of attention and thereby indexes a component of attention distinct from dot-probe indices.

Furthermore, relationships between attention bias and anxiety, as well as its risk factors, appear to be context-dependent beyond method and change according to factors such as testing environment, stimuli used, modality (e.g., reaction time, stationary versus mobile eye-tracking, event-related potentials), and participant age. For example, Fu et al. (2019) found no group differences in attention bias to threat between anxious and non-anxious children when using stationary eye-tracking, but differences emerged when using mobile eye-tracking.

Additionally, it is worth mentioning that we are powered at 72% to predict a medium effect (i.e., a correlation coefficient of .3) and powered at 99% to predict a large effect (i.e., a correlation coefficient of .5). Thus, for the analyses wherein we examined the correlations between threat-bias and anxiety measures, we were moderately powered to detect medium and large effects. A meta-analysis by Dudeney et al. (2015) on attentional bias and anxiety in children found small effect sizes of the relationship between anxiety and attentional bias ($d = .21$) and age as a moderator ($\beta = .04$). A priori analyses suggested that we would require a sample size of $N = 568$ to detect small effect sizes for correlations and interactions. Hence, we are underpowered to detect a small effect (i.e., correlation coefficient of .1), power = 13%. In other words, results from the current study suggest that there is not a significant medium or large effect of the relationship between threat-related attentional bias and anxiety in young children, as well as age as a moderator, but there may be small effect sizes that were undetectable due to the lack of power. Hence, we wish to emphasize that the lack of significant findings in the relationship between threat-related attentional bias and anxiety is not due to the lack of psychometric reliability in the eye-tracking measures.

Another limitation of this study is the use of only parent-reported measures of anxiety. While parents may be reliable and valid reporters of anxiety, future studies may find additional value in obtaining teacher reports, self-reports, and observational measures of anxiety. Of note, the rate of diagnosis in our sample is higher relative to the national average of 5–17% in children (Cartwright-Hatton et al., 2006; Costello et al., 2005; Ghandour et al., 2019). It is possible that there may be some selection bias, given that our lab studies anxiety (our lab website mentions this fact, and families with more anxious children may be more inclined to participate in our studies). Additionally, some regional variation may have accounted for the higher rates of anxiety. Other weaknesses of this study include the use of a sample of convenience as well as the relatively small sample size.

Overall, findings in the present study showed that it is possible to obtain psychometrically reliable measures of attentional bias using eye-tracking in young children. Although anxiety measures were not related to threat and neutral proportion dwell time or attentional bias, this is consistent with theories suggesting that individual differences in attentional biases to threat may emerge later in development.

DATA SHARING

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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CONFLICT OF INTEREST

None.

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ENDNOTES

[1]The practice of creating residualized difference scores is common in previous studies (Meyer et al., 2017).

[2]The same pattern of results emerged when the analyses were conducted using gaze frequency to threat faces and first fixation to threat faces.

[3]Furthermore, we excluded **N** = 7 children with a specific phobia-only diagnosis (i.e., no other anxiety) from the analyses and found that the pattern of results was similar. Threat dwell times and attentional bias scores, as well as neutral dwell times and attentional bias scores, did not differ by the presence of an anxiety disorder diagnosis, **p**s > .10. We also investigated if child age and threat attentional bias scores interacted to predict anxiety diagnosis status. The overall model was not significant, **p** = .62. Main effects of threat attentional bias and child age did not significantly predict anxiety diagnosis status, **coeff** = −8.21, **SE** = 6.49, **z** = −1.27, **p** = .21, and **coeff** = −0.00, **SE** = 0.42, **z** = −0.00, **p** = 1.00, respectively. The child age × anxiety diagnosis status interaction was not significant, **coeff** = 3.58, **SE** = 8.52, **z** = 0.42, **p** = .67.

REFERENCES

Aiken, L. S., West, S. G., & Reno, R. R. (1991). *Multiple regression: Testing and interpreting interactions*. Sage.

Amir, N., Klumpp, H., Elias, J., Bedwell, J. S., Yanasak, N., & Miller, L. S. (2005). Increased activation of the anterior cingulate cortex during processing of disgust faces in individuals with social phobia. *Biological Psychiatry*, *57*(9), 975–981.

Armstrong, T., & Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review*, *32*(8), 704–723.

Bar-Haim, Y. (2010). Research review: Attention bias modification (ABM): A novel treatment for anxiety disorders. *Journal of Child Psychology and Psychiatry*, *51*(8), 859–870.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & Van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin*, *133*(1), 1.

Bar-Haim, Y., Morag, I., & Glickman, S. (2011). Training anxious children to disengage attention from threat: A randomized controlled trial. *Journal of Child Psychology and Psychiatry*, *52*(8), 861–869.

Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. *Behaviour Research and Therapy*, *35*(1), 49–58.

Beesdo, K., Knappe, S., & Pine, D. S. (2009). Anxiety and anxiety disorders in children and adolescents: Developmental issues and implications for DSM-V. *Psychiatric Clinics*, *32*(3), 483–524.

Beesdo, K., Pine, D. S., Lieb, R., & Wittchen, H. U. (2010). Incidence and risk patterns of anxiety and depressive disorders and categorization of generalized anxiety disorder. *Archives of General Psychiatry*, *67*(1), 47–57.

Benoit, K. E., McNally, R. J., Rapee, R. M., Gamble, A. L., & Wiseman, A. L. (2007). Processing of emotional faces in children and adolescents with anxiety disorders. *Behaviour Change*, *24*(4), 183–194.

Birmaher, B., Brent, D. A., Chiappetta, L., Bridge, J., Monga, S., & Baugher, M. (1999). Psychometric properties of the Screen for Child Anxiety Related Emotional Disorders (SCARED): A replication study. *Journal of the American Academy of Child & Adolescent Psychiatry*, *38*(10), 1230–1236.

Birmaher, B., Khetarpal, S., Brent, D., Cully, M., Balach, L., Kaufman, J., & Neer, S. M. (1997). The screen for child anxiety related emotional disorders (SCARED): Scale construction and psychometric characteristics. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(4), 545–553.

Bodden, D. H., Dirksen, C. D., Bogels, S. M., Nauta, M. H., De Haan, E., Ringrose, J., Appelboom, C., Brinkman, A. G., & Appelboom-Geerts, K. C. (2008). Costs and cost-effectiveness of family CBT versus individual CBT in clinically anxious children. *Clin Child*

Psychol Psychiatry, *13*(4), 543–564. https://doi.org/10.1177/1359104508090602

Britton, J. C., Bar-Haim, Y., Carver, F. W., Holroyd, T., Norcross, M. A., Detloff, A., Leibenluft, E., Ernst, M., & Pine, D. S. (2012). Isolating neural components of threat bias in pediatric anxiety. *Journal of Child Psychology and Psychiatry*, *53*(6), 678–686.

Brown, H. M., Eley, T. C., Broeren, S., Macleod, C., Rinck, M., Hadwin, J. A., & Lester, K. J. (2014). Psychometric properties of reaction time based experimental paradigms measuring anxiety-related information-processing biases in children. *Journal of Anxiety Disorders*, *28*(1), 97–107. https://doi.org/10.1016/j.janxdis.2013.11.004

Burris, J. L., Buss, K., LoBue, V., Pérez-Edgar, K., & Field, A. P. (2019). Biased attention to threat and anxiety: On taking a developmental approach. *Journal of Experimental Psychopathology*, *10*(3), 2043808719860717.

Cartwright-Hatton, S., McNicol, K., & Doubleday, E. (2006). Anxiety in a neglected population: Prevalence of anxiety disorders in pre-adolescent children. *Clinical Psychology Review*, *26*(7), 817–833.

Chang, S. W., Kuckertz, J. M., Bose, D., Carmona, A. R., Piacentini, J., & Amir, N. (2019). Efficacy of attention bias training for child anxiety disorders: A randomized controlled trial. *Child Psychiatry & Human Development*, *50*(2), 198–208.

Cooper, R. M., Bailey, J. E., Diaper, A., Stirland, R., Renton, L. E., Benton, C. P., Penton-Voak, I. S., Nutt, D. J., & Munafò, M. R. (2011). Effects of 7.5% CO_2 inhalation on allocation of spatial attention to facial cues of emotional expression. *Cognition and Emotion*, *25*(4), 626–638.

Costafreda, S. G., Brammer, M. J., David, A. S., & Fu, C. H. Y. (2008). Predictors of amygdala activation during the processing of emotional stimuli: A meta-analysis of 385 PET and fMRI studies. *Brain Research Reviews*, *58*(1), 57–70.

Costello, E. J., Egger, H. L., & Angold, A. (2005). The developmental epidemiology of anxiety disorders: Phenomenology, prevalence, and comorbidity. *Child and Adolescent Psychiatric Clinics of North America*, *14*(4), 631–648. https://doi.org/10.1016/j.chc.2005.06.003

Creswell, C., Woolgar, M., Cooper, P., Giannakakis, A., Schofield, E., Young, A. W., & Murray, L. (2008). Processing of faces and emotional expressions in infants at risk of social phobia. *Cognition and Emotion*, *22*(3), 437–458.

Dalgleish, T., Taghavi, R., Neshat-Doost, H., Moradi, A., Canterbury, R., & Yule, W. (2003). Patterns of processing bias for emotional information across clinical disorders: A comparison of attention, memory, and prospective cognition in children and adolescents with depression, generalized anxiety, and posttraumatic stress disorder. *Journal of Clinical Child and Adolescent Psychology*, *32*(1), 10–21.

De Voogd, E. L., Wiers, R. W., Prins, P. J. M., & Salemink, E. (2014). Visual search attentional bias modification reduced social phobia in adolescents. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(2), 252–259.

Dodd, H. F., Hudson, J. L., Williams, T., Morris, T., Lazarus, R. S., & Byrow, Y. (2015). Anxiety and attentional bias in preschool-aged children: An eyetracking study. *Journal of Abnormal Child Psychology*, *43*(6), 1055–1065. https://doi.org/10.1007/s10802-014-9962-x

Dudeney, J., Sharpe, L., & Hunt, C. (2015). Attentional bias towards threatening stimuli in children with anxiety: A meta-analysis. *Clinical Psychology Review*, *40*, 66–75.

Eysenck, M. (2014). *Anxiety and cognition: A unified theory*. Psychology Press.

Field, A. P. (2006a). The behavioral inhibition system and the verbal information pathway to children's fears. *Journal of Abnormal Psychology*, *115*(4), 742. https://doi.org/10.1037/0021-843X.115.4.742

Field, A. P. (2006b). Watch out for the beast: Fear information and attentional bias in children. *Journal of Clinical Child and Adolescent Psychology*, *35*(3), 431–439. https://doi.org/10.1207/s15374424jccp3503_8

Field, A. P., & Lester, K. J. (2010). Is there room for 'development' in developmental models of information processing biases to threat in children and adolescents? *Clinical Child and Family Psychology Review*, *13*(4), 315–332. https://doi.org/10.1007/s10567-010-0078-8

Fu, X., Nelson, E. E., Borge, M., Buss, K. A., & Pérez-Edgar, K. (2019). Stationary and ambulatory attention patterns are differentially associated with early temperamental risk for socioemotional problems: Preliminary evidence from a multimodal eye-tracking investigation. *Development and Psychopathology*, *31*(3), 971–988.

Gamble, A. L., & Rapee, R. M. (2010). The time-course of attention to emotional faces in social phobia. *Journal of Behavior Therapy and Experimental Psychiatry*, *41*(1), 39–44. https://doi.org/10.1016/j.jbtep.2009.08.008

Ghandour, R. M., Sherman, L. J., Vladutiu, C. J., Ali, M. M., Lynch, S. E., Bitsko, R. H., & Blumberg, S. J. (2019). Prevalence and treatment of depression, anxiety, and conduct problems in US children. *The Journal of Pediatrics*, *206*, 256–267.

Gorday, J. Y., & Meyer, A. (2018). Linking puberty and error-monitoring: Relationships between self-reported pubertal stages, pubertal hormones, and the error-related negativity in a large sample of children and adolescents. *Developmental Psychobiology*, *60*(4), 483–490.

Hadwin, J. A., Donnelly, N., Richards, A., French, C. C., & Patel, U. (2009). Childhood anxiety and attention to emotion faces in a modified stroop task. *British Journal of Developmental Psychology*, *27*(2), 487–494.

Kaufman, J., Birmaher, B., Brent, D., Rao, U., Flynn, C., Moreci, P., Williamson, D., & Ryan, N. (1997). Schedule for affective disorders and schizophrenia for school-age children-present and lifetime version (K-SADS-PL): Initial reliability and validity data. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(7), 980–988.

Kessler, R. C., Avenevoli, S., Costello, E. J., Georgiades, K., Green, J. G., Gruber, M. J., He, J.-P., Koretz, D., McLaughlin, K. A., & Petukhova, M. (2012). Prevalence, persistence, and sociodemographic correlates of DSM-IV disorders in the National Comorbidity Survey Replication Adolescent Supplement. *Archives of General Psychiatry*, *69*(4), 372–380.

Kessler, R. C., Foster, C. L., Saunders, W. B., & Stang, P. E. (1995). Social consequences of psychiatric disorders, I: Educational attainment. *American Journal of Psychiatry*, *152*(7), 1026–1032.

Kindt, M., & Van Den Hout, M. (2001). Selective attention and anxiety: A perspective on developmental issues and the causal status. *Journal of Psychopathology and Behavioral Assessment*, *23*(3), 193–202.

Kindt, M., Van Den Hout, M., De Jong, P., & Hoekzema, B. (2000). Cognitive bias for pictorial and linguistic threat cues in children. *Journal of Psychopathology and Behavioral Assessment*, *22*(2), 201–219.

Koolschijn, P. C. M. P., Schel, M. A., de Rooij, M., Rombouts, S. A. R. B., & Crone, E. A. (2011). A three-year longitudinal functional magnetic resonance imaging study of performance monitoring and test-retest reliability from childhood to early adulthood. *Journal of Neuroscience*, *31*(11), 4204–4212.

Last, C. G., Perrin, S., Hersen, M., & Kazdin, A. E. (1996). A prospective study of childhood anxiety disorders (Vol. 35 SRC - GoogleScholar).

Lay, C., Kovacs, A., & Danto, D. (1998). The relation of trait procrastination to the big-five factor conscientiousness: An assessment with primary-junior school children based on self-report scales. *Personality and Individual Differences*, *25*(2), 187–193.

Lazarov, A., Abend, R., & Bar-Haim, Y. (2016). Social anxiety is related to increased dwell time on socially threatening faces. *Journal of Affective Disorders*, *193*, 282–288.

Lazarov, A., Pine, D. S., & Bar-Haim, Y. (2017). Gaze-contingent music reward therapy for social anxiety disorder: A randomized controlled trial. *American Journal of Psychiatry*, *174*(7), 649–656.

Linetzky, M., Kahn, M., Lazarov, A., Pine, D. S., & Bar-Haim, Y. (2019). Gaze-contingent music reward therapy for clinically anxious 7- to 10-year-olds: An open multiple baseline feasibility study. *Journal of Clinical Child & Adolescent Psychology*, *49*(5), 618–625. https://doi.org/10.1080/15374416.2019.1573685

Lisk, S., Vaswani, A., Linetzky, M., Bar-Haim, Y., & Lau, J. Y. F. (2020). Systematic review and meta-analysis: Eye-tracking of attention to threat in child and adolescent anxiety. *Journal of the American Academy of Child & Adolescent Psychiatry*, *59*(1), 88–99.

LoBue, V. (2010). And along came a spider: An attentional bias for the detection of spiders in young children and adults. *Journal of Experimental Child Psychology*, *107*(1), 59–66.

LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear-relevant stimuli by adults and young children. *Psychological Science*, *19*(3), 284–289.

Lowther, H., & Newman, E. (2014). Attention bias modification (ABM) as a treatment for child and adolescent anxiety: A systematic review. *Journal of Affective Disorders*, *168*, 125–135.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska directed emotional faces (KDEF). CD ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institutet, 91(630), 2-2.

MacKinnon, D. P., Lockwood, C. M., & Williams, J. (2004). Confidence limits for the indirect effect: Distribution of the product and resampling methods. *Multivariate Behavioral Research*, *39*(1), 99–128.

MacLeod, C., & Clarke, P. J. F. (2015). The attentional bias modification approach to anxiety intervention. *Clinical Psychological Science*, *3*(1), 58–78.

Mancebo, M. C., Boisseau, C. L., Garnaat, S., Eisen, J. L., Greenberg, B., Sibrava, N. J., Stout, R. L., & Rasmussen, S. A. (2014). Long-term course of pediatric obsessive-compulsive disorder: three years of prospective follow-up. Comprehensive psychiatry.

Meyer, A., Lerner, M. D., De Los Reyes, A., Laird, R. D., & Hajcak, G. (2017). Considering ERP difference scores as individual difference measures: Issues with subtraction and alternative approaches. *Psychophysiology*, *54*(1), 114–122.

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behavior Research and Therapy*, *36*(9), 809–848.

Mogg, K., & Bradley, B. P. (2006). Time course of attentional bias for fear-relevant pictures in spider-fearful individuals. *Behavior Research and Therapy*, *44*(9), 1241–1250. https://doi.org/10.1016/j.brat.2006.05.003

Monk, C. S., Nelson, E. E., McClure, E. B., Mogg, K., Bradley, B. P., Leibenluft, E., Blair, R. J. R., Chen, G., Charney, D. S., & Ernst, M. (2006). Ventrolateral prefrontal cortex activation and attentional bias in response to angry faces in adolescents with generalized anxiety disorder. *American Journal of Psychiatry*, *163*(6), 1091–1097.

Morales, S., Fu, X., & Pérez-Edgar, K. E. (2016). A developmental neuroscience perspective on affect-biased attention. *Developmental Cognitive Neuroscience*, *21*, 26–41.

Morales, S., Pérez-Edgar, K. E., & Buss, K. A. (2015). Attention biases towards and away from threat mark the relation between early dysregulated fear and the later emergence of social withdrawal. *Journal of Abnormal Child Psychology*, *43*(6), 1067–1078.

Pérez-Edgar, K., Bar-Haim, Y., McDermott, J. M., Chronis-Tuscano, A., Pine, D. S., & Fox, N. A. (2010). Attention biases to threat and behavioral inhibition in early childhood shape adolescent social withdrawal. *Emotion*, *10*(3), 349.

Pine, D. S., Cohen, P., Gurley, D., Brook, J., & Ma, Y. (1998). The risk for early-adulthood anxiety and depressive disorders in adolescents with anxiety and depressive disorders. *Archives of General Psychiatry*, *55*(1), 56–64.

Posner, M. I., Rothbart, M. K., Sheese, B. E., & Voelker, P. (2012). Control networks and neuromodulators of early development. *Developmental Psychology*, *48*(3), 827.

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers*, *36*(4), 717–731.

Price, R. B., Wallace, M., Kuckertz, J. M., Amir, N., Graur, S., Cummings, L., Popa, P., Carlbring, P., & Bar-Haim, Y. (2016). Pooled patient-level meta-analysis of children and adults completing a computer-based anxiety intervention targeting attentional bias. *Clinical Psychology Review*, *50*, 37–49.

Rakison, D. H., & Derringer, J. (2008). Do infants possess an evolved spider-detection mechanism? *Cognition*, *107*(1), 381–393. https://doi.org/10.1016/j.cognition.2007.07.022

Rodebaugh, T. L., Scullin, R. B., Langer, J. K., Dixon, D. J., Huppert, J. D., Bernstein, A., Zvielli, A., & Lenze, E. J. (2016). Unreliability as a threat to understanding psychopathology: The cautionary tale of attentional bias. *Journal of Abnormal Psychology*, *125*(6), 840.

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at three to seven years: The Children's Behavior Questionnaire. *Child Development*, *72*(5), 1394–1408.

Schmukle, S. C. (2005). Unreliability of the dot probe task. *European Journal of Personality*, *19*(7), 595–605.

Schofield, C. A., Johnson, A. L., Inhoff, A. W., & Coles, M. E. (2012). Social anxiety and difficulty disengaging threat: Evidence from eye-tracking. *Cognition and Emotion*, *26*(2), 300–311. https://doi.org/10.1080/02699931.2011.602050

Shechner, T., Jarcho, J. M., Britton, J. C., Leibenluft, E., Pine, D. S., & Nelson, E. E. (2013). Attention bias of anxious youth during extended exposure of emotional face pairs: An eye-tracking study. *Depression and Anxiety*, *30*(1), 14–21.

Shechner, T., Rimon-Chakir, A., Britton, J. C., Lotan, D., Apter, A., Bliese, P. D., Pine, D. S., & Bar-Haim, Y. (2014). Attention bias modification treatment augmenting effects on cognitive behavioral therapy in children with anxiety: Randomized controlled trial. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*(1), 61–71.

Skinner, I. W., Hubscher, M., Moseley, G. L., Lee, H., Wand, B. M., Traeger, A. C., Gustin, S. M., & McAuley, J. H. (2018). The reliability of eyetracking to assess attentional bias to threatening words in healthy individuals. *Behavior Research Methods*, *50*(5), 1778–1792. https://doi.org/10.3758/s13428-017-0946-y

Spence, S. H., Donovan, C., & Brechman-Toussaint, M. (1999). Social skills, social outcomes, and cognitive features of childhood social phobia. *Journal of Abnormal Psychology*, *108*(2), 211.

Staugaard, S. R. (2009). Reliability of two versions of the dot-probe task using photographic faces. *Psychology Science Quarterly*, *51*(3), 339–350.

Van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. W. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin*, *140*(3), 682.

Vasey, M. W., Daleiden, E. L., Williams, L. L., & Brown, L. M. (1995). Biased attention in childhood anxiety disorders: A preliminary study. *Journal of Abnormal Child Psychology*, *23*(2), 267–279.

Waechter, S., Nelson, A. L., Wright, C., Hyatt, A., & Oakman, J. (2014). Measuring attentional bias to threat: Reliability of dot probe and eye movement indices. *Cognitive Therapy and Research*, *38*(3), 313–333.

Waechter, S., & Stolz, J. A. (2015). Trait anxiety, state anxiety, and attentional bias to threat: Assessing the psychometric properties of response time measures. *Cognitive Therapy and Research*, *39*(4), 441–458.

Waters, A. M., Henry, J., Mogg, K., Bradley, B. P., & Pine, D. S. (2010). Attentional bias towards angry faces in childhood anxiety disorders. *Journal of Behavior Therapy and Experimental Psychiatry*, *41*(2), 158–164.

White, L. K., Degnan, K. A., Henderson, H. A., Pérez-Edgar, K., Walker, O. L., Shechner, T., Leibenluft, E., Bar-Haim, Y., Pine, D. S., & Fox, N. A. (2017). Developmental relations among behavioral inhibition, anxiety, and attention biases to threat and positive information. *Child Development*, *88*(1), 141–155.

Zavos, H. M., Rijsdijk, F. V., Gregory, A. M., & Eley, T. C. (2010). Genetic influences on the cognitive biases associated with anxiety and depression symptoms in adolescents. *Journal of Affective Disorders*, *124*(1–2), 45–53.

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