AMERICAN PSYCHOLOGICAL ASSOCIATION

Journal of Abnormal Psychology

ISSN: 0021-843X

2020, Vol. 129, No. 7, 701–712
http://dx.doi.org/10.1037/abn0000623

Trajectories of Anxiety When Children Start School: The Role of Behavioral Inhibition and Attention Bias to Angry and Happy Faces

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Extensive research has examined attention bias to threat in the context of anxiety in adults, but little is understood about this association in young children, and there is a dearth of longitudinal research examining whether attention bias to threat predicts anxiety over time in childhood. In the current study, a sample of 180 children participated in a longitudinal study, first as preschoolers and again as they transitioned to formal schooling. At baseline, children aged 3–4 years completed a free-viewing eye-tracking task with angry-neutral and happy-neutral face pairs and an assessment of behavioral inhibition (BI). At follow-up, parents provided daily reports of their child's state anxiety over a 2-week period as their child started school and completed a measure of their child's anxiety symptoms. Results indicated that, on average, preschool-aged children exhibit a bias for emotional faces that is stronger for angry than happy faces. There was little evidence that this bias was associated with anxiety symptoms. However, BI interacted with dwell bias for angry faces to predict trajectories of anxiety over the transition to school. An unexpected interaction between BI and dwell bias for happy faces was also found, with dwell for happy faces associated with lower anxiety for children higher in BI. The findings are consistent with recent developmental models of the BI-anxiety relationship and indicate that attention bias modification may not be suitable for young children, for whom attention bias to threat may be normative.

General Scientific Summary
Preschool predictors of children's anxiety symptoms and state anxiety (reported daily) over the transition to school at age 4 were examined. Specifically, attention biases to angry and happy faces, relative to neutral, and an avoidant temperament style known as behavioral inhibition (BI) were examined as predictors. BI predicted anxiety symptoms and state anxiety. There was no evidence that attention biases directly predicted anxiety, although biases interacted with temperament to predict trajectories of state anxiety over the transition.

Keywords: anxiety, children, attention bias, emotional faces, transition to school

Supplemental materials: http://dx.doi.org/10.1037/abn0000623.supp

This article was published Online First August 17, 2020.

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Thank you to all the Watch Them Grow families for your time and support for our research. Also, thanks to Hannah Stearne, Katy Whittle, Francesca Inzani, Charlotte Lewis-Pryde, Charlie Murphy, Shellie May, and Ola Lowicka for their help with the running of the project. The text message data collection was conducted by www.synapta.co.uk. The research was supported by an ESRC Future Leaders Fellowship awarded to Helen F. Dodd (ES/L010119/1) and a Royal Society Grant awarded to Helen F. Dodd (RG2014R2).

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Early cognitive models defined biased attention as a central mechanism underpinning anxiety (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Williams, Watts, MacLeod, & Mathews, 1988), and extensive research has evaluated this hypothesis. There is some evidence for an anxiety-linked attention bias for threat (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007), although this is not consistently found (Kruijt, Parsons, & Fox, 2019), and there are concerns about the reliability of attention bias tasks (Rodebaugh et al., 2016). In attention bias theory and research, anxiety is typically defined broadly to include clinical and nonclinical samples as well as state and trait anxiety. This broad definition of anxiety also aligns with The National Institute of Mental Health Research Domain Criteria (National Institute of Mental Health, 2011) and theoretical ideas about the relationship between anxiety disorders and trait and state anxiety (e.g., Raymond, Steele, & Seriès, 2017).

Over the past two decades, there has been growing interest in anxiety-linked attention bias in children. Using reaction time (RT) tasks analogous to those used with adults, some developmental studies support an anxiety-linked bias (e.g., Abend et al., 2018), but there are inconsistencies. For instance, biases *away* from threat have been found in certain anxiety disorders (Salum et al., 2013; Waters, Bradley, & Mogg, 2014), and some studies have found no association between anxiety and attention bias in childhood (e.g., Britton et al., 2013). A recent meta-analysis including studies of clinically diagnosed and community samples found that anxiety is associated with an attention bias for threat in children, but this effect is smaller than that found in a meta-analysis of the adult literature (Bar-Haim et al., 2007) and is weaker in younger children (Dudeney, Sharpe, & Hunt, 2015).

Despite this increased interest, there remains a dearth of research focused on anxiety-linked attention bias in young children; the lowest average age of participants in studies included in the Dudeney et al. (2015) meta-analysis was 9 years. Assessing bias in young children is challenging due to a reliance on RT tasks. Such tasks are problematic because motor responses are distal from attentional processing, and young children have slower and more variable motor functioning (Price et al., 2015; Van Damme & Crombez, 2009). Indeed, Brown et al. (2014) showed that RT-based measures of attentional bias have poor reliability in children. In contrast, eye tracking can have better accuracy and reliability (Price et al., 2015; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014), although this is not consistently found and can vary depending on the metric extracted from the gaze data (Skinner et al., 2018). Eye tracking also has the advantage that it can be used in free-viewing paradigms that do not require complex instructions.

Eye tracking has successfully been employed to investigate patterns of anxiety-linked attention bias in children. Some of this research suggests that anxious youth exhibit an orientation bias for angry versus neutral faces (Shechner et al., 2013), but other studies have reported more nuanced results (Schmidtendorf, Wiedau, Asbrand, Tuschen-Caffier, & Heinrichs, 2018) or effects that vary by age (Gamble & Rapee, 2009). A recent meta-analysis concluded that eye-tracking studies with children and adolescents do not support an anxiety-linked vigilance bias for threat (Lisk, Vaswani, Linetzky, Bar-Haim, & Lau, 2019). In the only study to have examined anxiety-linked biases specifically in young children, both anxious and nonanxious 3–4-year-olds exhibited orientation and dwell biases for angry over neutral faces, with no between-group differences (Dodd et al., 2015).

Various theories have been proposed regarding the role of attention bias in anxiety (see Mogg & Bradley, 2016 for a review). Across these theories, two differing perspectives emerge (Mogg & Bradley, 2018). Some theorists argue that attention bias is relatively stable and plays a causal role in anxiety (MacLeod & Clarke, 2015), acting as a vulnerability factor that leads to elevated anxiety when a stressful event occurs (Mathews & MacLeod, 2002). Others argue that attention bias may not play a causal role in anxiety, instead acting as a maintenance factor (Mogg & Bradley, 1998).

Two main lines of adult research have investigated whether attention bias plays a causal role in anxiety: attention bias modification (ABM) studies and longitudinal studies (see Van Bockstaele et al., 2014 for a review). In support of the causal hypothesis, several studies suggest that ABM can decrease anxiety in adults (Bar-Haim, 2010) and youth (Pettit et al., 2019). However, notable inconsistencies across studies exist, and the debate about whether ABM can successfully decrease anxiety symptoms continues (Cristea, Kok, & Cuijpers, 2015; Grafton et al., 2017; Mogg, Waters, & Bradley, 2017). Longitudinal research with adults also provides support for the causal hypothesis. For example, MacLeod and Hagan (1992) found that attention to threat-related words predicted emotional distress in women following a medical diagnosis. Similar findings have been reported in other adult populations, such as in the study by Van Den Hout, Tenney, Huygens, Merckelbach, and Kindt (1995), in which attentional bias was a significant predictor of reactions to life stress in healthy participants and was a better predictor than trait anxiety. A crucial feature of these longitudinal studies is that they examine state responses to a stressor. This is relevant to anxiety disorders because it is theorized, and supported by the evidence extant, that anxiety disorders involve a primary malfunction in the brain's ability to regulate anxious states (Raymond et al., 2017). Therefore, studying state anxiety in response to a stressor is relevant for understanding risk for anxiety disorders.

Longitudinal research examining whether attention bias predicts anxiety in children is rare and, to our knowledge, has not examined response to a stressor. In developmental research, attention bias has typically been examined alongside the temperament style behavioral inhibition (BI). Children high in BI are characterized by withdrawal and wariness in unfamiliar, novel situations (Kagan, Reznick, Clarke, Snidman, & Garciacoll, 1984). Extensive evidence suggests that BI is a predictor of subsequent social reticence and anxiety (Chronis-Tuscano et al., 2009; Clauss & Blackford, 2012; Hudson, Murayama, Meteyard, Morris, & Dodd, 2018). However, not all children who are high in BI go on to experience difficulties with anxiety (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001), and various moderators of the BI-anxiety relationship have been proposed (Degnan & Fox, 2007) including individual differences in cognitive processing biases, such as attentional bias (Liu & Pérez-Edgar, 2019).

Emerging research provides fairly consistent evidence that child temperament and attention bias interact to affect anxiety and social withdrawal (Cole, Zapp, Fettig, & Pérez-Edgar, 2016; Morales, Pérez-Edgar, & Buss, 2015). Pérez-Edgar et al. (2010) found that BI in early childhood predicted adolescent social withdrawal only when adolescents also had an attention bias to threat. These findings were subsequently supported in younger children, with BI in early life predicting social withdrawal at age 5 only in those with concurrent attention bias (Pérez-Edgar et al., 2011). Two follow-up assessments of this same sample revealed similar patterns for trait anxiety at ages 7 (White et al., 2017) and 10 (Nozadi et al., 2016). Such findings indicate that attention bias may be a core mechanism sustaining BI over development, resulting in elevated risk for social reticence and anxiety (Henderson, Pine, & Fox, 2015). To our knowledge, the studies conducted by White et al. (2017) and Nozadi et al. (2016) are the only longitudinal studies that have evaluated whether attention bias predicts anxiety over time in children, and importantly, neither considered children's state anxiety in response to a stressor. Furthermore, these studies relied on RT-based measures of attention bias.

The present research had three aims: first, to evaluate whether attention bias to threat and BI predict children's concurrent anxiety symptoms; second, to evaluate whether attention bias to threat and BI predict children's anxiety symptoms prospectively; and third, to examine whether attention bias to threat and BI predict children's state anxiety in response to a stressor. We made use of starting school as a naturalistic stressor, hypothesizing that anxiety trajectories over the transition to school, as well as anxiety symptoms at baseline and follow-up, will be predicted by BI and by an attention bias for angry faces and that attention bias for angry faces will interact with BI to predict anxiety.

Method

Participants

A sample of 180 typically developing children aged 3.42–4.83 years ($M = 3.97$, $SD = 0.25$; 90 female) were recruited via preschools, public advertising, social media, and word of mouth to take part in a project about children's emotions when they start school. Most children were described by their parent as being White British (83.3%). See online supplemental materials for power analysis details and further sample information.

Follow-up took place as children started school. The average time between baseline and starting school was 6.19 months ($SD =$ 2.25 months; range = 3–11 months).

Apparatus and Materials

Parent report of BI. The Behavioral Inhibition Questionnaire (BIQ; Bishop, Spence, & McDonald, 2003) is a parent-report measure with 30 items. Parents are asked to indicate how often each behavior occurs for their child. The measure has good psychometric properties, adequate internal consistency, moderate stability of time, and strong construct validity (Bishop et al., 2003; Kim et al., 2011). In this sample, Cronbach's alpha was .96.

Observation of BI. The two fear episodes most relevant to BI (Risk Room and Stranger Approach) from the Laboratory Temperament Assessment Battery (Lab-TAB) were used. The Lab-TAB is a standardized observational measurement of temperament designed for use with 3–5-year-old children (Gagne, Van Hulle, Aksan, Essex, & Goldsmith, 2011). Further details of the procedure for these episodes can be found in the online supplemental materials and Lab-TAB manual (Goldsmith, Reilly, Lemery, Longley, & Prescott, 1999).

Episodes were videotaped and coded according to the Lab-TAB manual. Scores for each coding criteria were reverse coded as necessary so that higher scores indicated more inhibited responses. These scores were then converted into *z*-scores individually and then averaged into a single BI score ($M = -0.04$, $SD = 0.44$, range $= -0.74$–1.53) in line with previous research (Gagne et al., 2011; Goldsmith et al., 1999). To check reliability, a secondary coder coded 24% of the Lab-TAB assessments. Interrater reliability was good to excellent, ICC(2,1) = .95, 95% CI [.91, .98]. Both coders were blind to the child's anxiety scores and bias scores.

Overall BI score. Children's scores on the BIQ and their observed BI scores were correlated, $r = .32$, $p < .001$, and were combined by converting both measures into *z*-scores and averaging. For 17 participants, this combined score was missing due to technical problems while completing the Lab-TAB.

Parent report of anxiety symptoms. The Preschool Anxiety Scale (PAS; Spence, Rapee, McDonald, & Ingram, 2001) is designed for parents of children aged 2.5–6.5 years, and the total score provides an overall measure of child anxiety symptoms (or trait anxiety). The measure has good construct validity, satisfactory internal consistency, and good cross-informant and test–retest reliability (Spence et al., 2001). Cronbach's alpha at both baseline and follow-up was .91. There was no missing data at baseline, but 16 participants were missing follow-up PAS scores. These children did not differ from those with PAS scores on anxiety, age, gender, ethnicity, parent marital status, or parent employment status.

Parent report of daily anxiety during transition to school. State anxiety ratings were obtained via text messages sent daily to parents over the transition to school period. The text message read, "Please reply with your rating for [Child's name]'s anxiety today. Using a scale from 0 to 10, with 0 indicating no anxiety or worries at all and 10 indicating extremely anxious/worried." Parents were also asked to reply indicating whether their child had attended school that day and how much of a problem their child's anxiety had been. For the latter, the responses were very highly correlated with the level of anxiety ($r = .83$), so the focus here is on anxiety ratings only. Construct validity of this measure is provided by correlations between average anxiety score reported via text and PAS total score at both baseline and follow-up (see Table 1). At least 7 days of ratings were provided for 179 of the 180 participants; 150 responded on all 14 days. Overall, only 2.5% of anxiety ratings were missing. The mean number of days that ratings were given was 13.56 ($SD = 1.19$; minimum = 7 days).

Attention Bias Task

Eye-tracking apparatus. Eye movements were measured using a remote desk-mounted Tobii T300 eye tracker. The task was programmed in e-prime Version 2.0.10.356 (Psychology Software Tools, Pittsburgh, PA) and presented on a Viewsonic VA2413wm 24-in. monitor with 1920 × 1080 resolution. The e-prime script is available from the corresponding author.

Face stimuli. Color photographs of 16 Caucasian child actors (eight male and eight female), each displaying neutral, angry, and happy facial affect, were sourced from the Child Affective Facial Expression set (CAFE; LoBue & Thrasher, 2015). Happy faces were included as well as angry faces to ensure any observed effects could be attributed to the threatening, angry faces specifically as opposed to emotional faces in general. The faces chosen had the

Table 1
Means, Standard Deviations, and Correlations With Confidence Intervals

Variable	*M*	*SD*	1	2	3	4	5
1. Dwell bias angry faces	0.14	0.08	—				
2. Dwell bias happy faces	0.03	0.06	.29** [.14, .42]				
3. Baseline PAS	23.79	14.47	−.12 [−.26, .04]	−.07 [−.22, .08]			
4. Follow-up PAS	22.43	13.65	−.06 [−.22, .10]	−.09 [−.25, .07]	.76** [.69, .82]		
5. BI	−0.01	0.81	.01 [−.15, .16]	−.02 [−.17, .14]	.54** [.42, .64]	.46** [.32, .58]	
6. Average daily anxiety rating	1.64	1.39	−.06 [−.21, .09]	−.11 [−.26, .04]	.45** [.32, .56]	.54** [.42, .64]	.35** [.21, .48]

Note. PAS = Preschool Anxiety Scale; BI = behavioral inhibition. Values in square brackets indicate the 95% confidence intervals.
** $p < .01$.

highest available accuracy ratings. The CAFE images are aligned based on each actor's individual eye alignment. The photographs were manipulated so that all images from the same actor were matched for RGB values as well as mean and standard deviation luminance. Photographs were resized to 178 × 187 at 60 ppi. The face stimuli were positioned to center at 761 × 540 and 1159 × 540. The viewing distance was approximately 65 cm, giving a viewing angle of 4.4° to the center of the screen and 9.4° between the center points of the face stimuli.

Design. The task began with a nine-point eye-tracker calibration. Each trial began with a fixation screen for 500 ms showing a central cross surrounded by a 2-in. square purple outline to highlight the fixation cross. Gaze contingency was used such that the experimental screen began only after the participant had fixated within the square for a minimum of 100 ms. The fixation screen was then replaced by the experimental screen for 1,500 ms. The experimental screen consisted of an emotion (happy/angry) and neutral face displayed side by side of the same child (positions counterbalanced). There were 64 trials (32 happy-neutral, 32 angry-neutral).

To make the task engaging for children, on 15 additional trials, a cartoon monkey was presented centrally. Fifteen images were used, each showing the monkey in a different position (hanging from a branch, sitting arms crossed, etc.). The ordering of experimental and monkey screens was randomized. Monkey screens remained until the experimenter pressed a resume button.

Eye-tracking data. Eye-movement data was continuously recorded during stimulus presentation (1,500 ms) at a sampling rate of 300 Hz. This means that the position of the left and right eye was recorded every 3.33 ms. Each of these samples was then processed in relation to three areas of interest (AOIs) defined based on the location of the two face images and the square surrounding the fixation cross.

The raw eye-tracking data were processed in R Version 3.4.2 using EyetrackingR (Dink & Ferguson, 2018). Four participants did not start the task due to problems calibrating, and three were excluded because they did not complete the task. Fixation plots were visually inspected, and five additional participants were excluded given evidence of calibration drift. Data was therefore available for 168/180 participants (93%). Individual trials were removed if there was greater than 40% track loss for that trial. On average, the included sample had 59.3 valid trials and < 8% track loss. Excluded participants did not differ significantly from included participants on age, sex, ethnicity, BI score, baseline PAS score, follow-up PAS score, or average anxiety rating (all *p*s > .1). The following bias scores were calculated for use in the analyses.

Orientation bias. Orientation bias for angry faces was calculated as the percentage of angry-neutral trials where participants looked to a face, in which gaze was recorded within the angry face AOI first. The equivalent was also calculated for happy faces. The split-half estimate of reliability was calculated using splithalf in R (Parsons, 2019; Parsons, Kruijt, & Fox, 2019) and was $r_{sb} = -.18$, 95% CI [−.34, .01] for bias to angry faces and $r_{sb} = -.33$, [−.46, −.17] for bias to happy faces. Given these poor reliability estimates, no analyses were conducted using orientation bias.

Dwell bias. The position of participant gaze was sampled and recorded every 3.33 ms, or at 300 Hz. To calculate dwell bias for angry faces, the number of samples recorded in the angry face AOI and neutral face AOI during angry-neutral trials were calculated as a proportion of the total number of on-screen samples recorded during each trial, and the resulting proportion of looking to the neutral face was subtracted from proportion of looking to the angry face. The equivalent was calculated for happy dwell bias using happy-neutral trials. The split-half estimate of reliability was calculated using splithalf in R (Parsons, 2019; Parsons et al., 2019) and was $r_{sb} = .63$, 95% CI [.53, .71] for bias to angry faces and $r_{sb} = .39$, [.23, .53] for bias to happy faces.

Procedure Baseline

Procedures were approved by the University of Reading Research Ethics Committee (UREC 16/56). Informed consent and assent were obtained from parents and participants after being provided with information about the project. Families were invited to a lab session during which they completed the tasks reported here, as well as other tasks forming part of a larger longitudinal study. The Lab-TAB was completed prior to the eye-tracking task. For the eye-tracking task, participants were told that they were going to play a game using a computer that knew where they were looking. They were given a sheet displaying the 15 cartoon monkeys and were told they needed to look out for each one on the screen. Participants were told that lots of faces would also appear on the screen. One of the researchers sat with the participant throughout the task to encourage engagement and provide support with the monkey checklist. At the end of the lab session, participants were thanked for their participation and given a small gift; parents were given £35.

Procedure Follow-Up

Parents consented to take part in the follow-up stage of the research during the baseline session. The follow-up stage included

14 days of daily ratings of anxiety obtained via text message and online questionnaires. Text messages were sent every evening at 7:30 p.m. beginning 2 days before the child's first day at school. Reminder texts were sent the following morning if no response was received. Parents were e-mailed approximately 1 week after their child started school, asking them to complete a series of questionnaires online. A reminder e-mail was sent 2 weeks later, and the online questionnaire was closed approximately 6 weeks after the children's first day at school.

Missing Data

Full details regarding missing data are shown in the online supplemental materials. Missing data were handled using mice (van Buuren & Groothuis-Oudshoorn, 2011), meaning that all participants and available data were included in analyses. In total, only 6% of all data were missing at baseline. At follow-up, 9% of PAS anxiety scores were missing, and 2.5% of text message daily ratings were missing. In terms of participant numbers, 152 had complete data at baseline. Of these, 137 had PAS follow-up data (76% of the sample), and all had >7 days of state anxiety ratings.

Data Analysis Plan

Analyses were conducted in R Version 3.5.3 using the tidyverse suite (Wickham, 2017). No potential confounds were identified. Linear regression was used to examine whether BI and attention bias predict PAS anxiety scores at baseline, addressing Aim 1, and at follow-up, addressing Aim 2. Growth curve analysis (GCA) was then used to examine whether BI and attention bias predict trajectories of anxiety over the transition to school, addressing Aim 3. All variables were centered prior to analysis.

Assumption Checks

For all variables, distributions were evaluated, and checks for univariate and multivariate outliers were conducted. Two issues were found. First, the anxiety rating data was negatively skewed; 44% of the 2,520 data points were zeros, meaning that nonlinear transformations did not lead to a distribution that was approximately normal. Consequently, for the GCAs involving this variable, robust maximum likelihood estimators were used. One participant was an outlier on the anxiety ratings measure, but their inclusion did not affect the pattern of results, so they are included.

Results

The data set and analysis code are available to download, along with other measures collected as part of the wider study, at https://reshare.ukdataservice.ac.uk/854392/. Given the poor reliability of the orientation bias variables, no analyses were conducted using these variables. The results focus only on dwell bias.

Table 1 shows the descriptive statistics for each of the variables and the correlations between variables. Anxiety symptoms at baseline and follow-up were aligned with PAS norms for 3- and 4-year-olds (norms as follows: $M = 22.86$, $SD = 15.57$; $M = 18.81$, $SD = 13.90$, respectively), indicating that anxiety levels of the sample were representative of the general population. Anxiety symptoms were highly correlated, and both were correlated with the average daily anxiety rating. BI was associated with anxiety at baseline and follow-up as well as average daily anxiety rating. There was little evidence for a direct association between attention bias and anxiety. Table 1 shows that dwell bias for happy faces and for angry faces were significantly correlated. Given this, we will examine whether findings are consistent with both dwell bias variables in the same model after evaluating the effects for happy and angry faces separately.

Characterization of Attention Bias

One-sample *t* tests using complete data indicated that the sample as a whole exhibited a significant dwell bias to both angry, $t(167) = 23.37$, $p < .001$, 95% CI [0.13, 0.15], $d = 1.80$, and happy, $t(167) = 5.94$, $p < .001$, [0.019, 0.04], $d = 0.45$, faces. Bias for angry was significantly stronger than the bias for happy, $t(331.71) = 5.03$, $p < .001$.

Predicting Anxiety Symptoms at Baseline

Linear models were conducted with 20 imputed data sets. Anxiety symptoms at baseline was the outcome variable, and attention bias and BI, together with their interaction, were predictor variables. Two models were conducted for angry and happy dwell bias (see Table 2). Across all models, BI was a significant predictor ($p < .001$). There were no significant main effects of the attention bias variables. The interaction between dwell bias for happy faces and BI approached significance ($p = .06$). When dwell bias for angry faces and dwell bias for happy faces were included in the same regression model (see Table 2), there were no significant main effects or interactions that included the attention bias variables, although the BI by dwell bias for angry faces approached significance ($p = .06$).

Predicting Anxiety Symptoms at Follow-Up

Equivalent linear models were conducted with anxiety symptoms at follow-up as the outcome variable (see Table 3). The pattern of results was identical to baseline. Across all models, BI was a significant predictor ($p < .001$). There were no significant main effects of the attention bias variables and no significant interactions between BI and attention bias, although the interaction between dwell bias for happy faces and BI was significant ($p = .04$). A small negative association between dwell bias for happy faces and anxiety was apparent but only for children higher in BI. When dwell bias for angry faces and dwell bias for happy faces were included in the same regression model (see Table 3), there were no significant main effects or interactions that included the attention bias variables ($p > .08$).

Predicting Anxiety Over the Transition to School

We examined whether BI and dwell bias to angry and happy faces were predictors of anxiety trajectories over the transition to school period using GCA with the lme4 (Bates, Mächler, Bolker, & Walker, 2014) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017) packages. Data from 20 imputed data sets were pooled to give the results reported. The model selection process is outlined in the online supplemental materials. The final models and results are shown in Tables 4, 5, and 6. Across models, there was consistently a significant main effect of BI,

Table 2
Regression Results for Cross-Sectional Analyses Predicting Anxiety Scores on the Preschool Anxiety Scale

Model/variable	Standardized beta	95% CIs	Statistic	*df*	*p*	R^2
Dwell bias to angry faces						.31, 95% CI [.19, .42]
Intercept	−0.01	[−0.13, 0.12]	−0.11	168.50	.91	
BI	0.54	[0.41, 0.67]	8.29	155.99	<.001**	
Bias	−0.12	[−0.25, 0.02]	−1.75	141.34	.08	
BI × Bias	0.001	[−0.15, 0.15]	0.01	153.81	.99	
Dwell bias to happy faces						.31, 95% CI [.20, .43]
Intercept	−0.01	[−0.13, 0.12]	−0.10	166.51	.92	
BI	0.55	[0.42, 0.67]	8.49	161.23	<.001**	
Bias	−0.07	[−0.20, 0.05]	−1.14	151.94	.25	
BI × Bias	−0.14	[−0.28, 0.003]	−1.93	149.09	.06	
Dwell bias to angry and happy faces						.32, 95% CI [.21, .43]
Intercept	−0.01	[−0.14, 0.11]	−0.20	158.61	.84	
BI	0.54	[0.41, 0.66]	8.25	153.02	<.001**	
H.Bias	−0.05	[−0.18, 0.09]	−0.66	144.66	.51	
A.Bias	−0.09	[−0.23, 0.04]	−1.35	152.20	.18	
BI × H.Bias	−0.12	[−0.27, 0.02]	−1.59	137.11	.11	
BI × A.Bias	0.00	[−0.15, 0.16]	0.06	134.16	.95	
H.Bias × A.Bias	0.01	[−0.11, 0.12]	0.11	145.56	.91	
BI × H.Bias × A.Bias	0.02	[−0.13, 0.16]	0.23	143.41	.82	

Note. CI = confidence interval; BI = behavioral inhibition; A.Bias = dwell bias for angry faces; H.Bias = dwell bias for happy faces.
** $p < .01$.

as expected; children higher in BI had greater anxiety scores over the transition to school. There was also a significant linear effect of time in all models; over time, children's anxiety decreased.

Angry faces. For dwell bias for angry faces (see Table 4), no main effect was found, but there was a significant three-way interaction between dwell bias for angry faces, BI, and quadratic time ($p = .005$). This interaction is shown in Figure 1. The figure suggests that attention bias affected the pattern of anxiety over time for the high-BI children, with high-BI children who also had an attention bias to threat having the highest levels of anticipatory anxiety during the 2 days before starting school, which declined quite rapidly once they started school. In contrast, high-BI children with a relatively low attention bias to threat showed a slight increase in anxiety as they started school, which began to decline after the first few days at school. For low-BI children, those who also had a relatively low attention bias to threat showed higher levels of anxiety overall and particularly in advance of starting school, compared to those who had a higher attention bias to angry faces.

Happy faces. For dwell bias to happy faces (see Table 5), there was a significant main effect of BI ($p < .001$) and a

Table 3
Regression Results for Longitudinal Analyses Predicting Anxiety Scores on the Preschool Anxiety Scale at Follow-Up

Model/variable	Standardized beta	95% CIs	Statistic	*df*	*p*	R^2
Dwell bias to angry faces						.22, 95% CI [.10, .33]
Intercept	−0.005	[−0.14, 0.13]	−0.07	150.85	.94	
BI	0.45	[0.31, 0.60]	6.21	120.18	<.001**	
Bias	−0.04	[−0.19, 0.10]	−0.61	132.70	.54	
BI × Bias	<.01	[−0.16, 0.16]	<.001	138.55	.99	
Dwell bias to happy faces						.24, 95% CI [.13, .36]
Intercept	−0.004	[−0.14, 0.13]	−0.06	150.41	.95	
BI	0.46	[0.32, 0.6]	6.48	125.76	<.001**	
Bias	−0.08	[−0.22, 0.05]	−1.20	145.57	.23	
BI × Bias	−0.16	[−0.31, 0.001]	−2.10	127.59	.04*	
Dwell bias to angry and happy faces						.25, 95% CI [.14, .37]
Intercept	−0.01	[−0.14, 0.12]	−0.16	148.67	.87	
BI	0.46	[0.32, 0.6]	6.54	128.24	<.001**	
H.Bias	−0.08	[−0.22, 0.07]	−1.03	136.89	.31	
A.Bias	−0.02	[−0.16, 0.13]	−0.23	119.28	.82	
BI × H.Bias	−0.14	[−0.29, 0.01]	−1.74	130.91	.08	
BI × A.Bias	0.02	[−0.15, 0.19]	0.26	101.13	.80	
H.Bias × A.Bias	0.01	[−0.11, 0.14]	0.22	120.08	.83	
BI × H.Bias × A.Bias	−0.02	[−0.17, 0.13]	−0.27	134.48	.79	

Note. CI = confidence interval; BI = behavioral inhibition; A.Bias = dwell bias for angry faces; H.Bias = dwell bias for happy faces.
* $p < .05$. ** $p < .01$.

Table 4
Coefficients of Final Model for Dwell Bias for Angry Faces

Term	Estimate	p	95% CIs	Random effect variance
(Intercept)	1.64	<.001**	[1.44, 1.83]	1.57
BI	0.47	<.001**	[0.27, 0.67]	—
Bias	−0.09	.37	[−0.30, 0.11]	—
Time	−0.44	<.001**	[−0.50, −0.38]	—
$Time^2$	<.01	.997	[−0.06, 0.06]	—
BI × Bias	−0.01	.97	[−0.26, 0.25]	—
BI × Time	−0.02	.61	[−0.08, 0.05]	—
BI × $Time^2$	−0.05	.12	[−0.12, 0.03]	—
Bias × Time	0.02	.96	[−0.07, 0.07]	—
Bias × $Time^2$	0.02	.55	[−0.05, 0.08]	—
BI × Bias × Time	−0.05	.25	[−0.12, 0.03]	—
BI × Bias × $Time^2$	0.12	.005**	[0.04, 0.20]	—
Residual variance	—	—	—	2.29

Note. CI = confidence interval; BI = behavioral inhibition.
** $p < .01$.

significant main effect of linear time ($p < .001$). There was no significant main effect of dwell bias to happy faces, but there was a significant interaction between BI, dwell bias to happy faces, and linear time ($p = .001$). This interaction is shown in Figure 2, which indicates that high-BI children who had a lower dwell bias to happy faces had the highest levels of anxiety in anticipation of starting school but then showed a steeper decline relative to other groups.

Happy and angry faces. When dwell bias to angry faces and dwell bias to happy faces were included in the same model (see Table 6), the interactions observed in the separate models remained significant. No other main effects or interactions that included the attention bias variables were found.

Discussion

We evaluated whether, in young children, attention bias for threat is associated with trait anxiety and state anxiety in response to a stressor. In line with previous developmental work and theoretical models, attention bias was examined together with BI. Given poor split-half reliability estimates for the orientation bias variables, the results are based on dwell bias only. As expected, BI was a robust, significant predictor of anxiety symptoms at baseline and follow-up, as well as state anxiety over the transition to school. Contrary to our hypotheses, there was little evidence for a direct association between attention bias to angry or happy faces and anxiety and no evidence for an interaction between BI and attention bias to threat in predicting anxiety symptoms at baseline or follow-up. Nevertheless, the hypothesis that BI and attention bias to threat would interact to predict trajectories of state anxiety over the transition to school was supported. We also found an unexpected interaction between dwell bias to happy faces and BI in predicting state anxiety.

On average, children exhibited a bias for both angry and happy faces. This bias for angry faces fits with a large body of developmental research demonstrating that an attention bias to threat is normative and present from infancy (e.g., LoBue, 2009; LoBue & DeLoache, 2010). The bias for happy faces was subtle but is in keeping with recent evidence that attention is focused on happy faces (Bucher & Voss, 2019). Bias for angry faces and bias for happy faces were positively correlated, which suggests that at least some children may exhibit an underlying bias for emotional faces in general. Given this, we evaluated whether the results remained the same when happy and angry bias were included in the same model. For the state anxiety analyses, the results were identical,

Table 5
Coefficients of Final Model for Dwell Bias for Happy Faces

Term	Estimate	p	95% CIs	Random effect variance
(Intercept)	1.64	<.001**	[1.44, 1.83]	1.53
BI	0.47	<.001**	[0.27, 0.67]	—
Bias	−0.13	.20	[−0.33, 0.07]	—
Time	−0.44	<.001**	[−0.50, −0.38]	—
BI × Bias	−0.20	.07	[−0.42, 0.01]	—
BI × Time	−0.02	.53	[−0.09, 0.05]	—
Bias × Time	0.04	.30	[−0.03, 0.10]	—
BI × Bias × Time	0.11	.002**	[0.04, 0.18]	—
Residual variance	—	—	—	2.30

Note. CI = confidence interval; BI = behavioral inhibition.
** $p < .01$.

Table 6
Coefficients of Model for Dwell Bias With Angry and Happy Faces

Term	Estimate	*p*	95% CIs	Random effect variance
(Intercept)	1.63	<.001**	[1.42, 1.82]	1.56
BI	0.47	<.001**	[0.26, 0.66]	—
Angry bias	−0.04	.69	[−0.25, 0.17]	—
Happy bias	−0.11	.31	[−0.32, 0.1]	
Time	−0.44	<.001**	[−0.5, −0.37]	—
Time^2	0.01	.82	[−0.05, 0.07]	
BI × Angry Bias	0.01	.95	[−0.24, 0.26]	—
BI × Happy Bias	−0.20	.09	[−0.42, 0.03]	
Angry Bias × Happy Bias	0.08	.39	[−0.1, 0.27]	
BI × Time	−0.02	.55	[−0.08, 0.04]	—
BI × Time^2	−0.05	.13	[−0.11, 0.01]	
Angry Bias × Time	−0.02	.57	[−0.09, 0.05]	—
Angry Bias × Time^2	0.01	.82	[−0.06, 0.07]	
Happy Bias × Time	0.05	.17	[−0.02, 0.12]	
Happy Bias × Time^2	0.06	.10	[−0.01, 0.13]	
BI × Angry Bias × Happy Bias	−0.10	.42	[−0.33, 0.13]	
BI × Angry Bias × Time	−0.06	.15	[−0.13, 0.02]	—
BI × Angry Bias × Time^2	0.11	<.001**	[0.03, 0.19]	
BI × Happy Bias × Time	0.12	<.001**	[0.04, 0.19]	
BI × Happy Bias × Time^2	0.03	.50	[−0.05, 0.1]	
Angry Bias × Happy Bias × Time	0.01	.74	[−0.05, 0.07]	
Angry Bias × Happy Bias × Time^2	−0.01	.78	[−0.06, 0.05]	
BI × Angry Bias × Happy Bias × Time	−0.03	.51	[−0.1, 0.05]	
BI × Angry Bias × Happy Bias × Time^2	−0.05	.23	[−0.12, 0.02]	
Residual variance	—	—	—	2.28

Note. CI = confidence interval; BI = behavioral inhibition. This model includes quadratic and linear time to align with the highest-order model when angry bias and happy bias were examined alone.
$^{**}p < .01$.

which allows us to confidently interpret these findings as being specific to each emotion.

Overall, there was little evidence that 3–4-year-old children have an anxiety-related attention bias, which is consistent with previous eye-tracking research with young children (Dodd et al., 2015) and the conclusion of a recent meta-analysis of eye-tracking studies in children and adolescents (Lisk et al., 2019). A bias to threat early in life without clear evidence of an anxiety-linked bias is consistent with what Field and Lester (2010) termed the *moderation model*, where attention bias to threat is normative in young children and the association between bias and anxiety emerges with development. This, of course, assumes that an anxiety-linked bias is reliably present in older children and adults. While meta-analyses of attention bias studies have supported this link with anxiety (e.g., Bar-Haim et al., 2007; Dudeney et al., 2015), a recent meta-analysis of data that are arguably less likely to be affected by publication bias suggests that anxiety is not characterized by attention bias toward threat (Kruijt et al., 2019). Our results are also consistent with this conclusion.

State anxiety in response to a stressor is considered a vulnerability marker for subsequent trait anxiety and anxiety disorders (Raymond et al., 2017) and is therefore relevant for identifying potential risk factors for anxiety disorders. Our results showed that BI interacted with attention bias to threat to predict anxiety trajectory across the transition to school. For children with high BI, having a high dwell bias to angry faces predicted high anticipatory anxiety followed by a steep decline over time. A similar pattern was seen for children with low BI, albeit at a lower overall level of anxiety, but in those who had a *low* dwell bias to angry faces. In comparison, children with high BI with a low dwell bias showed a slight increase in anxiety over the first days at school, followed by a shallower decline. A BI by threat bias interaction is in keeping with previous work (e.g., Pérez-Edgar et al., 2011; White et al., 2017), but our findings differ because attention bias was not a clear predictor of anxiety level. Instead, attention bias affected anxiety trajectory over time differently depending on level of BI.

Notably, for children who were relatively low in BI, having an attention bias for angry faces predicted less anxiety over the transition to school. We are reluctant to overinterpret this unpredicted finding, but this may indicate that attention bias to threat is adaptive for children who are generally disinhibited and take more risks. Alternatively, a combination of a threat-related attention bias and uninhibited behavior could mean that these children notice potential threats and, by approaching them with curiosity, quickly learn whether they are associated with negative outcomes or not.

We also found an unexpected interaction between happy dwell bias and BI predicting anxiety trajectory over the transition to school; dwell bias to happy faces was associated with lower levels of anxiety in children who were high in BI. The interaction remained significant after controlling for the effects of dwell bias to angry faces, which suggests that maintained attention to positive social stimuli might serve as a protective factor against state anxiety for children high in BI. This finding must be interpreted cautiously given it was not hypothesized, and the split-half reliability for the happy dwell bias score was relatively low. However, the result is consistent with a reanalysis by Shechner et al. (2012)

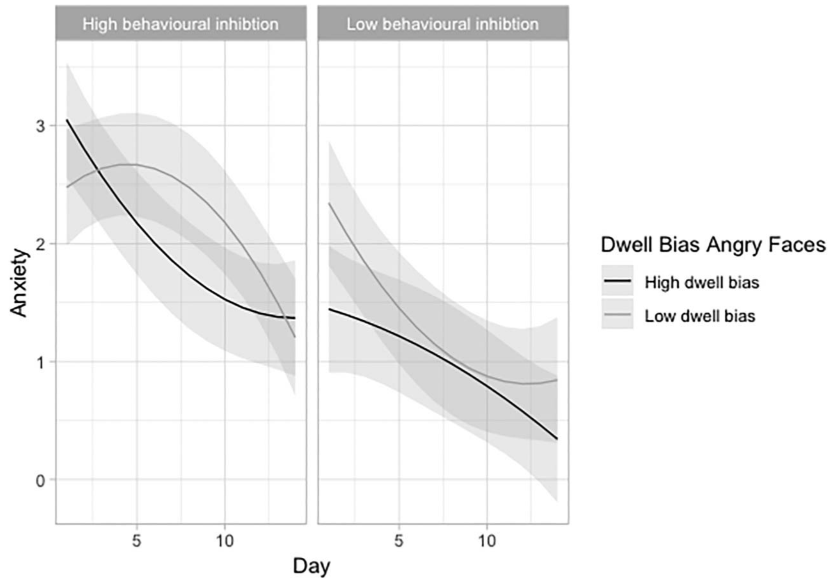

Figure 1. Interaction between dwell bias to angry faces, behavioral inhibition, and quadratic time. Lines indicate high and low orientation bias, and the two plots indicate high and low BI; both are operationalized as one standard deviation above and below the respective mean. Shading shows 95% confidence intervals.

using data from Pérez-Edgar et al. (2011), which showed that children who were high in BI *and* had a bias to happy faces had low anxiety relative to children who were high in BI *without* a bias to happy faces. Furthermore, work with children raised in institutions has shown that an attention bias for positive stimuli is associated with stable foster care placement, fewer internalizing symptoms, and better coping mechanisms (Troller-Renfree et al., 2017). ABM work has also shown that training a happy face bias significantly reduces anxiety severity in clinically anxious children (Waters, Pittaway, Mogg, Bradley, & Pine, 2013). Thus, there is emerging evidence that a positive bias might be protective for child anxiety, although it is noteworthy that attention bias for happy faces also has been linked to externalizing problems (Morales, Fu, & Pérez-Edgar, 2016).

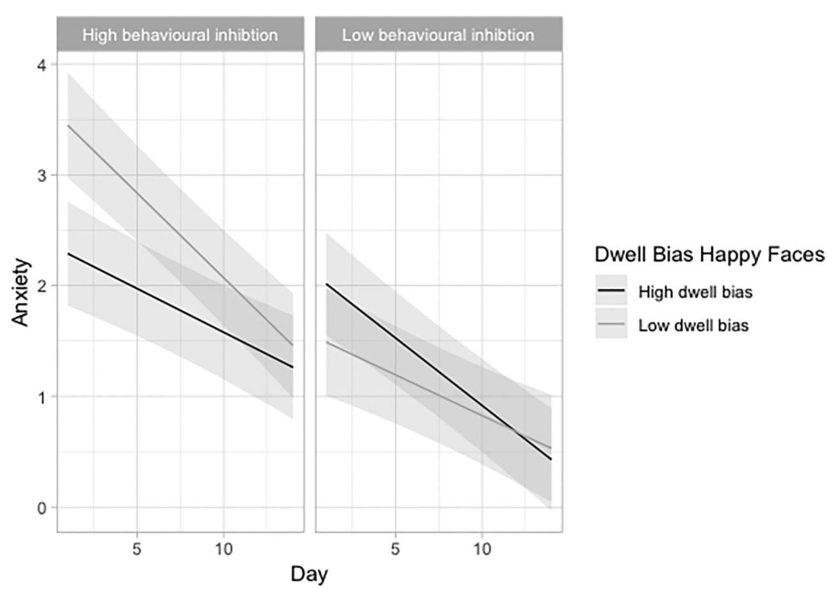

Figure 2. Interaction between dwell bias to happy faces, behavioral inhibition, and linear time. Lines indicate high and low dwell bias, and the two plots indicate high and low BI; both are operationalized as one standard deviation above and below the respective mean. Shading shows 95% confidence intervals.

Implications

Our findings indicate that ABM may not be suitable for young children as attention bias to threat appears to be normative for preschool-aged children. In fact, this might serve as an adaptive function, so we should be cautious about trying to change it. Furthermore, for both bias to angry and happy faces, consequences may vary depending on temperament. Given that starting school appears to only affect state anxiety over the initial school transition, it is unlikely that the costs of implementing programs in community settings to prevent anxiety over this period would be worthwhile. Nevertheless, it remains possible that targeting specific groups of children who are at risk would be valuable, but further work is required to identify which children would benefit and what this intervention should target specifically.

Strengths and Limitations

The study has a number of strengths. Of particular note is the longitudinal design using a normative stressor and the daily reports of anxiety allowing the trajectory of anxiety over the transition to school to be examined. To our knowledge, no previous research has examined whether BI or attention bias predict state anxiety in response to a stressor in children. Further strengths include the use of an age-appropriate eye-tracking task that does not rely on RT, as well as the excellent retention rate. Limitations include the self-selecting sample and the reliance on parent report to assess anxiety. Importantly, however, the predictors (BI, attention bias) did not rely on parent report, which diminishes concerns about shared method variance. Two further limitations require consideration. First, we evaluated split-half reliability of the eye-tracking bias scores and found poor reliability for orientation bias. In light of this, results for orientation bias are not presented, and we cannot make conclusions about initial allocation of attention. A number of studies have explicitly examined the reliability of metrics extracted from eye-tracking tasks, and there is some consensus across studies that orientation bias and other measures of "early" bias often have very poor reliability (Skinner et al., 2018). In contrast, measures of overall attention or dwell tend to have better reliability, which is consistent with our findings here. The reliability estimate for dwell bias to angry faces was adequate for individual difference research and consistent with eye-tracking reliability in adults (Sears, Quigley, Fernandez, Newman, & Dobson, 2019). For dwell bias to happy faces, reliability was weaker, and the results that rely on this measure should be considered with this in mind. A final limitation is that our sample was not clinically diagnosed. Longitudinal research aiming to identify opportunities for preventative interventions must begin by assessing putative risk factors *before* individuals meet criteria for disorder. Ideally, the dependent variable would then be subsequent disorder diagnosis, but for developmental research, this requires very large samples and long-term follow-up. An alternative is to have a dependent variable that is a marker of subsequent risk for disorder. For anxiety, both trait anxiety and state anxiety in response to a stressor are informative with regard to subsequent risk. This study has therefore been able to evaluate theoretical hypotheses and provide insights into risk mechanisms that are relevant for anxiety disorders using a nonclinical sample.

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Received November 5, 2019
Revision received May 21, 2020
Accepted May 21, 2020 ■