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RESEARCH ARTICLE

Mobile Eye Tracking Captures Changes in Attention Over Time During a Naturalistic Threat Paradigm in Behaviorally Inhibited Children

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Abstract

Attentional biases to and away from threat are considered hallmarks of temperamental behavioral inhibition (BI), which is a documented risk factor for social anxiety disorder. However, most research on affective attentional biases has traditionally been constrained to computer screens, where stimuli often lack ecological validity. Moreover, prior research predominantly focuses on momentary presentations of stimuli, rather than examining how attention may change over the course of prolonged exposure to salient people and objects. Here, in a sample of children oversampled for BI, we used mobile eye-tracking to examine attention to an experimenter wearing a "scary" or novel gorilla mask, as well as attention to the experimenter after mask removal as a recovery from exposure. Conditional growth curve modeling was used to examine how level of BI related to attentional trajectories over the course of the exposure. We found a main effect of BI in the initial exposure to the mask, with a positive association between level of BI and proportion of gaze allocated to the stranger's masked face over time. Additionally, there was a main effect of BI on proportion of gaze allocated to the stranger's face plus their mask during the recovery period when the mask was removed.

Keywords Attention bias · Behavioral Inhibition · Social threat · Eye tracking · Naturalistic paradigms · Fear

Introduction

Behavioral inhibition (BI) is a temperamental profile linked to markedly elevated risk for social anxiety disorder in adolescence and young adulthood (Chronis-Tuscano et al., 2009; Clauss & Blackford, 2012; Hirshfeld et al., 1992). Children high in BI may be characterized by an ensemble of behavioral and physiological markers including wariness to social novelty (Kagan et al., 1987; Rubin et al., 2002) and increased sympathetic nervous system activity (Kagan et al., 1987).

An extensive body of work suggests that an attentional bias *towards and away* from threatening stimuli may also be a characteristic of BI (Shackman et al., 2009; Szpunar & Young, 2012) or potentially a moderator of a child's risk for anxiety as a function of BI (Fu & Pérez-Edgar, 2019; White et al., 2017). For example, work by Pérez-Edgar and colleagues found that an attention bias to threat positively moderated the relation between BI and social withdrawal in both young childhood (Pérez-Edgar et al., 2011) and adolescence (Pérez-Edgar et al., 2010). However, not all studies have noted a strong relation between BI and attention patterns, and the directionality of attention (i.e., avoidance vs. vigilance) appears to shift with the specific task and context of testing (Fu et al., 2019; Heuer et al., 2007; Kashdan et al., 2014; Weeks et al., 2013).

The prioritization of affective stimuli is a normative process with implications in emotion regulation, where one's visual world may facilitate gating of emotional and cognitive responses (Amso & Scerif, 2015; Todd et al., 2012). However, children high in BI may be hypervigilant to

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environmental cues (Kagan et al., 1987) and over-extend patterns of attention to threat to items that are more benign, including social novelty (Fox et al., 2005). High levels of attention allocated to negatively valenced stimuli may potentiate negative affect, a hallmark of BI, impeding adaptive social functioning and promoting symptoms of anxiety. Thus, patterns of attention to threat present as a conceptual and mechanistic link between BI and anxiety (Lonigan et al., 2004).

Traditional methods of quantifying attention biases to threat rely on computerized tasks such as the dot probe, emotional Stroop, emotional visual search, and emotional spatial cueing (e.g., Affective Posner) tasks (Burris et al., 2019; Fu & Pérez-Edgar, 2019). While earlier iterations of these tasks have relied on a behavioral response, such as a button press, recent implementations have included stationary eye-tracking to quantify gaze and capture attentional processes preceding, or in the absence of, a motor response (Burris et al., 2017; Pérez-Edgar et al., 2017). In many of these classic assessments, stimuli are presented only briefly, often on the order of milliseconds. For example, the dot probe paradigm usually presents two adjacent faces for between 500 and 1000 ms. The task then measures latency to respond or saccade to a probe appearing in the same location as one of the faces (Fu & Pérez-Edgar, 2019; Pérez-Edgar et al., 2017), with longer latencies to fixate upon the probe in a location incongruent with an emotional face interpreted as a sign of bias to that emotion.

Such screen-based paradigms offer excellent experimental control but can lack ecological validity. The faces used in computer tasks are often static, nonresponsive, and lacking in social context, unlike the social stimuli actually encountered by humans on a daily basis (Ladouce et al., 2017; Risko et al., 2016). Emerging ambulatory data collection tools such as mobile eye-tracking allow us to quantify metrics, like visual attention, previously constrained to a computer screen. With mobile eye tracking, an individual is able to navigate their "real world" while gaze information is gathered. Prior work suggests that visual attention patterns in ecologically valid paradigms often do not match patterns captured during conceptually similar computer tasks (Foulsham & Kingstone, 2017; Fu et al., 2019; Grossman et al., 2019). For example, Foulsham and Kingstone (2017) found no significant concordance between fixation patterns while participants walked through a college campus with mobile eye tracking recordings and fixation patterns while the participants looked at static photos of the same campus on a computer screen. Therefore, mobile eye-tracking technology can provide added insights into how individuals attend to and navigate their environment.

Tasks relying on momentary exposures to emotionally valenced stimuli often portray attentional biases as a static construct, using summary statistics based on averages of looking behavior over repeated exposures to a category of stimuli. However, prior work has shown that behavior in response to potentially threatening stimuli may change over the duration of an exposure, with heterogeneity in these trajectories varying as a function of individual differences in approach and avoidance tendencies (Morales et al., 2017; Shewark et al., 2020). Yet, overt behavior captures only one of the multiple processes involved as an individual encounters social threat or social novelty. Work by Buss and colleagues (2013) found that across tasks with varied levels of presumed threat, temperamentally fearful children were differentiated in their behavior during a *lower* threat episode. Specifically, temperamentally fearful children showed higher levels of coded behavioral fear when a friendly stranger entered the room and asked the child a few questions. However, there were no significant differences in coded fear behavior during a *higher* threat episode. In particular, no differences were noted when the child entered a room to find an experimenter wearing a "scary mask" who then approached them (Buss et al., 2013). The high level of presumed threat, or novelty, in this encounter may work to minimize individual differences in behavioral response. However, other processes unfolding during these novel exchanges, such as visual attention, may help capture individual differences in response among children high in BI in a way that overt behavior does not.

For example, Henderson and Wilson (2017) suggest that a protracted return to baseline after attention is drawn to threatening stimuli, which may vary as a function of BI, may potentiate negative affect and thus increase anxious symptomology over time. The presumption is that a quick return to baseline minimizes the potential impact of anxiety-related mechanisms that may come into play during prolonged engagement and processing. Moreover, behavior may change as a child's perception of the threat changes, particularly if they gain new information suggesting that the stimulus is indeed not-so-threatening. Little research to date has directly examined how patterns of attention may change after threat level diminishes, and how individual differences may relate to any evident variation in attention patterns.

Prior research has established the importance of examining both naturalistic and dynamic measures of behavior but has generally neglected to examine these principles within the context of visual attention biases to threat. This study seeks to fill the current gap by examining change in attention patterns along more protracted time scales with changes in perceived threat level. We chose to use the "Scary Mask" task utilized in Buss et al (2013), which reported no differences in fear behavior as a function of temperament in a similar age range. It may be that even with exposure to this admittedly strange encounter children may be able to better regulate an overt affective response by early childhood. Alternately, the encounter is so surprising, novel, or threatening (or some combination) that it erases underlying individual differences. Either way, gaze may better characterize BI-linked individual difference than overt behavior. We also examine individual differences in recovery from exposure. In particular, we look to see if variation in BI impacts attention to the presumed environmental threat, a purported mechanism linking early temperament to the later emergence of social withdrawal and anxiety. We hypothesized that greater BI would relate to higher levels of attention to the masked stranger, under the assumption that it represents threat. In line with Buss et al (2013), we did not expect differences in overt fear behavior as a function of BI. We also hypothesized that BI level would be related to a slower decline in attention after the stranger takes off her mask, revealing her identity as a research assistant they had previously met, diminishing novelty, and conveying that the stranger is not actually a threat.

Method

Participants

Participants were 45 children ranging from 5 to 7 years of age (M = 6.15 years, *SD* = 0.64, 51.1% female) identifying as White (91.1%, *n* = 41), Asian (2.2%, *n* = 1), African American (2.2%, *n* = 1), Latino (2.2%, *n* = 1), and other (2.2%, *n* = 1), reflecting the demographics of the surrounding semi-rural community. Families were recruited using a University database of families expressing interest in participating in research studies, as well as community outreach and word-of-mouth. We oversampled for high levels of BI, such that 13 children (29%) in the final sample were classified as BI. Exclusion criteria for enrollment in the study included non-English speakers, gross developmental delays, or report of severe neurological or medical illnesses. All study procedures were approved by the Institutional Review Board at the Pennsylvania State University. All parents and children completed written consent/assent and were compensated for their time.

Prior to their lab visit, 163 children were screened for BI via parent report with the Behavioral Inhibition Questionnaire (BIQ; Bishop et al., 2003). Consistent with previous literature (Broeren & Muris, 2009; Fu et al., 2017; Poole et al., 2020), children were recruited as a BI participant if their total BIQ score was greater than or equal to 119 or if their social novelty subscale score was greater than or equal to 60. Thirty-nine children screened met the BI criteria.

After screening, all eligible children were invited to participate in the study. Twenty-three children were enrolled as pilot participants, as part of the grant's aim to refine mobile eye tracking as a methodology. Seventy children (20 BI) were brought to the lab as the final sample to complete a battery of episodes assessing temperamental reactivity, including the "Scary Mask" episode central to these analyses (described further below). The mean age of the sample was 6.11 years (*SD* = 0.60) with 34 females (48.8%). The sample predominantly identified as White (*n* = 61, 87.1%). Participants were excluded due to: poor calibration and/or tracking (*N* = 15), technical problems (*N* = 5), requesting removal of the eye tracker (*N* = 1), declining participation in the episode (*N* = 3), and being the twin of another participant (*N* = 1). In selecting participants for use in the final analysis, we were conservative in setting a threshold for data quality so as to minimize noise. Participants were excluded for poor calibration when a suitable calibration could not be agreed upon by two independent coders (see methods section). There were no significant differences in age, $t(44) = -0.81$, $p = 0.42$, or BI, $t(44) = -0.08$, $p = 0.94$, between the included and excluded participants. A visualization of the participant recruitment can be seen in Fig. 1.

Procedure

Parents completed a series of online questionnaires about themselves and their children prior to the laboratory visit.

Behavioral Inhibition The BIQ (Bishop et al., 2003) includes 30 questions that assess a child's response to novelty, using a Likert scale ranging from 1 ("Hardly Ever") to 7 ("Almost Always"). Although the BIQ was used to recruit participants and enrich the sample categorically, BI was assessed as a continuous variable in the analyses, such that higher scores reflected higher levels of BI (*M* = 90.93, *SD* = 26.63). The BIQ had good internal consistency in this study (Chronbach's α = 0.95). Even with our recruitment scheme of oversampling for higher levels of BI, BI was relatively normally distributed in this sample (skewness = −0.03).

Ambulatory Eye Tracker Participants wore a Pupil binocular ambulatory eye tracker (Pupil Labs; Kassner et al., 2014). The headset consists of two separate cameras, each pointing at an eye, as well as a third camera centered on the space immediately in front of the child, capturing their world view. Data were recorded either with Pupil Capture v.0.9.6 (Pupil Labs) installed on a Microsoft Surface Pro 3 tablet with Windows 10 used in an earlier phase of the larger study (*n* = 10 in final sample) or with Pupil Capture v.0.9.12 (Pupil Labs) installed on a MSI VR One Backpack PC also running Windows 10 (*n* = 35 in final sample). A monitor located in a separate room was remotely connected to the PC enclosed within the backpack for real-time monitoring of data quality during the experiment. The headset plus the backpack were light enough so as not to hinder naturalistic movement during the session. There were no significant differences in data quality across equipment for either the mask on,

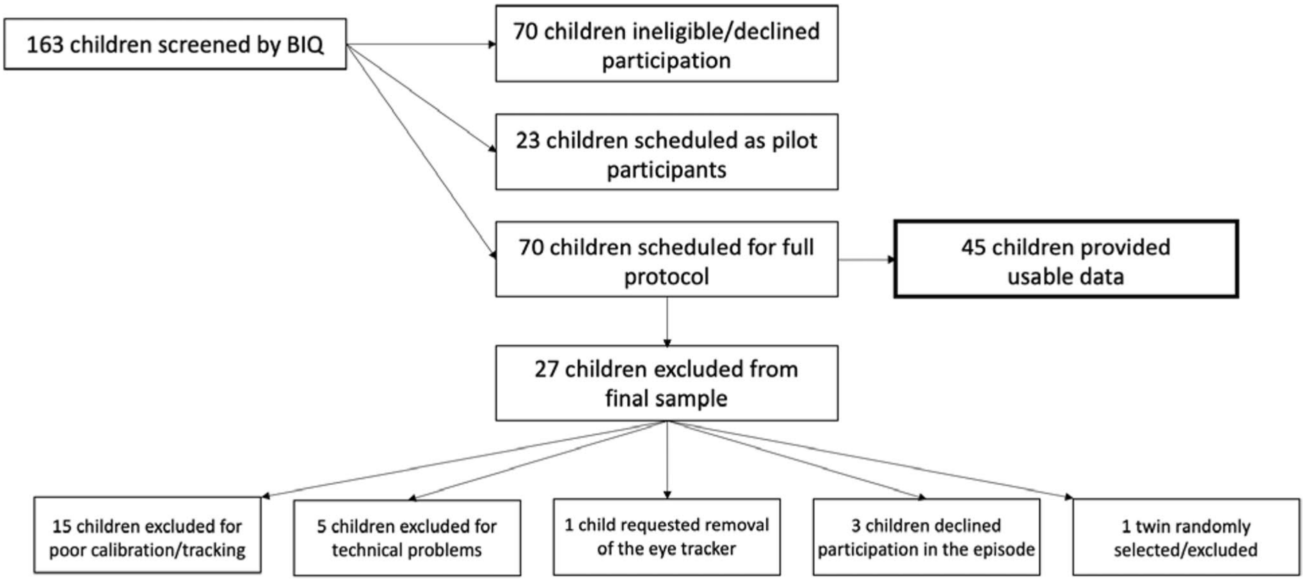


Fig. 1 Visualization of recruitment for the study

$t(44) = -0.98$, $p = 0.34$, or mask off, $t(44) = -1.69$, $p = 0.12$, portions of the task.

Similar to stationary eye-tracking paradigms, gaze was calibrated using a 5-point calibration on a large projection screen after the eye tracker and backpack were placed on the child. Children participated in other tasks as part of the larger study (e.g., Fu et al., 2019, Gunther et al., under review; MacNeill et al., 2021). The current task of interest was the last component of the visit protocol.

Scary Mask Episode The episode was adapted from the Preschool Laboratory Temperament Assessment Battery (Lab-TAB; Goldsmith et al., 1995) and was used to assess both attention to a threat and subsequent recovery over time. In this episode, the child enters the room to find a female experimenter in the corner, facing away from the child and wearing a black sweatshirt with a hood up. The experimenter turns around to face the child, revealing that she is wearing a gorilla mask. She takes two steps closer to the child before removing the mask, revealing a familiar experimenter (previously present in the Stranger Working episode adapted from Buss, 2011; see Gunther et al., under review). The experimenter reintroduces herself in a friendly fashion, saying she was just playing with a Halloween costume, and verbally invites the child to touch the mask before departing,

Eye Tracking Data Processing In order to quantitatively measure gaze to objects in the room, we overlaid gaze data on the child's world view as three concentric circles with crosshairs, using Pupil Player v.0.9.12 (Pupil Labs).

Gaze was also corrected to validation targets using Pupil Player v.0.9.12 (Pupil Labs). Before the task, the experimenter cued the child's attention to 5 points along a target while the child was instructed to look where they were pointing (http://bit.ly/MET_OSF). The validation for this task was conducted at a distance of 124 in (10 ft, 4 in), replicating the distance between the child and the masked experimenter at the beginning of the episode. Two independent coders examined each validation procedure to ensure that the indicated points were within the red circle of the gaze bullseye.

If gaze was discrepant from the cued locations in a consistent fashion (i.e., consistently skewed to the left), gaze corrections were made using the manual gaze correction plug-in in Pupil Player. Gaze corrections were completed by two trained independent coders. If corrections were within 0.03 units of each other on either the x- or y-axis, the master coder's corrections were used. If the discrepancy was greater than 0.03 units on the x- or y-axis, the two coders conferred to determine the best gaze correction. Following agreement, the video was exported with the corrected gaze and synced with synchronous room recordings using Final Cut Pro and exported at a resolution of 1920 × 1080 pixels at 30 frames per second. If the coders could not agree on a correction that allowed for the indicated points to be within the yellow circle of the gaze bullseye, the participant was removed from the sample for poor calibration/tracking ($N = 15$).

Gaze was coded frame-by-frame using Datavyu (Datavyu Team, 2014), based on published studies (Franchak & Adolph, 2010; Franchak et al., 2017; Fu et al., 2019; Gunther et al., under review; Kretch & Adolph, 2015; Kretch et al., 2014). Gaze to the following areas of interest (AOIs) were coded continuously: the mask, the experimenter's face (mask off), the experimenter's body, and the room. Coders marked the onset and offset of frames with the red circle on each AOI to determine looking behavior. Frames in which the red circle of the crosshairs was not visible were marked as indeterminate and thus not usable data. A primary coder coded 100% of each video, and a secondary coder coded a random selection of at least 20% of each video to ensure reliability. Coders agreed on an average of 91.9% of frames. We collapsed across the mask AOI and the experimenter's head AOI to create a general "stranger head" AOI to utilize in subsequent analyses.

The episode was divided into two phases: (1) experimenter mask on and (2) experimenter mask off (face visible). The episode was scripted for the experimenter, which yielded comparable phase times across participants. The entire episode was, on average, 102.88 s ($SD = 14.99$ s). For the mask on phase, the mean duration was 60.36 s ($SD = 5.60$ s), and for the mask off phase, the mean duration was 42.52 s ($SD = 13.19$ s). For each phase, data were parsed into one-second epochs using custom scripts in R (Version 3.6.2; R Core Team, 2013). Proportion of gaze to AOIs was computed by dividing total gaze to each AOI over the course of the epoch by the total amount of usable data during the epoch. Epochs in which gaze was not tracked were treated as missing data. Number of epochs for each child also varied by length of the episode, in that children with slightly shorter episodes had fewer epochs. Children provided an average of 103.40 epochs of data ($SD = 14.94$) across the entire episode (61.33 epochs, $SD = 5.64$, with mask on vs. 43.33 epochs, $SD = 13.18$, with mask removed). On average, 71.1% of frames provided were usable across the entire episode ($SD = 0.19$).

Behavioral Coding The Scary Mask episode was coded offline by trained and reliable coders using Datavyu (Datavyu Team, 2014). Coded behaviors included fear and proximity to the stimulus, the coding scheme based upon the Lab-TAB coding manual (Goldsmith et al., 1995). Fear was continuously coded based on event occurrences, which included facial expressions (e.g., eyelids raised and tense, mouth open with corners straight back, eyebrows straight), bodily expressions (e.g., freezing, visible muscle tensing, trembling), and vocal expressions (e.g., statements of being scared, high pitched vocal tone, crying). Fear was initially coded on an intensity scale from 0 to 3 with 0 as no fear and 3 as the most intense fear. Given a low base rate of highly intense fear, it was collapsed into a binary present or absent code. Subsequently, the total duration of fear in seconds was calculated (mask on: $M_{fear} = 43.72$ s, $SD_{fear} = 19.71$ s; mask off: $M_{fear} = 24.24$ s, $SD_{fear} = 20.10$ s).

Proximity to the stimulus was coded categorically with three categories, which included the following: the child was 2 or more feet away from the stranger/mask, within 2 ft of the stranger/mask, or touching the stranger/mask. Similar to fear, proximity was total duration in seconds spent in each category, with our variable of interest being the duration spent at the farthest proximity (mask on: $M_{far\ proximity} = 58.40$ s, $SD_{far\ proximity} = 10.51$ s; mask off: $M_{far\ proximity} = 16.12$ s, $SD_{far\ proximity} = 11.21$ s).

To account for variation in episode and phase duration, we generated proportion scores dividing each child's duration in a category by that child's time spent in the aligning mask on or mask off phase (mask on: $M_{fear} = 0.73$, $SD_{fear} = 0.32$, $M_{far\ proximity} = 0.97$, $SD_{far\ proximity} = 0.15$; mask off: $M_{fear} = 0.59$, $SD_{fear} = 0.43$, $M_{far\ proximity} = 0.39$, $SD_{far\ proximity} = 0.21$).

Reliability analysis was performed on content as well as timing of codes for 20% of the total number of videos coded (average interrater agreement = 86.4%, range 60–100%).

Statistical Analysis Growth curve modeling was used to assess trajectories of attention to the stranger over time, both during the initial threat exposure and the threat recovery periods. The proportion of tracked gaze to the stranger per second (which included the stranger's head and mask) for both the mask on and mask off periods were entered as repeated measures in the analysis and were the outcome measure of the model.

We first determined the best model fit for these data. We tested both linear and quadratic curves to see which trajectory, on average, provided a better fit. A quadratic curve was deemed most appropriate for both the mask on and mask off periods based on BIC (Figs. 2 and 3). For the mask on period, the BIC for a linear fit was 1395.65, while the BIC for a quadratic fit was 1324.34. For the mask off period, the BIC for a linear fit was 1439.01, while the BIC for a quadratic fit was 1116.76.

We then used conditional growth curve modeling to examine the influence of BI on trajectories of attention during and in recovery from threat, entering BI as a between-subjects predictor. The outcome of the model was proportion of gaze per one-second epoch within the mask on or mask off period. BIQ scores were mean centered for these analyses. Time and Time^2 were entered as random effects. All analyses were conducted in the NLME package in R (version 3.6.2; Pinheiro et al., 2021; R Core Team, 2013).

Model statements:
Within-Subjects

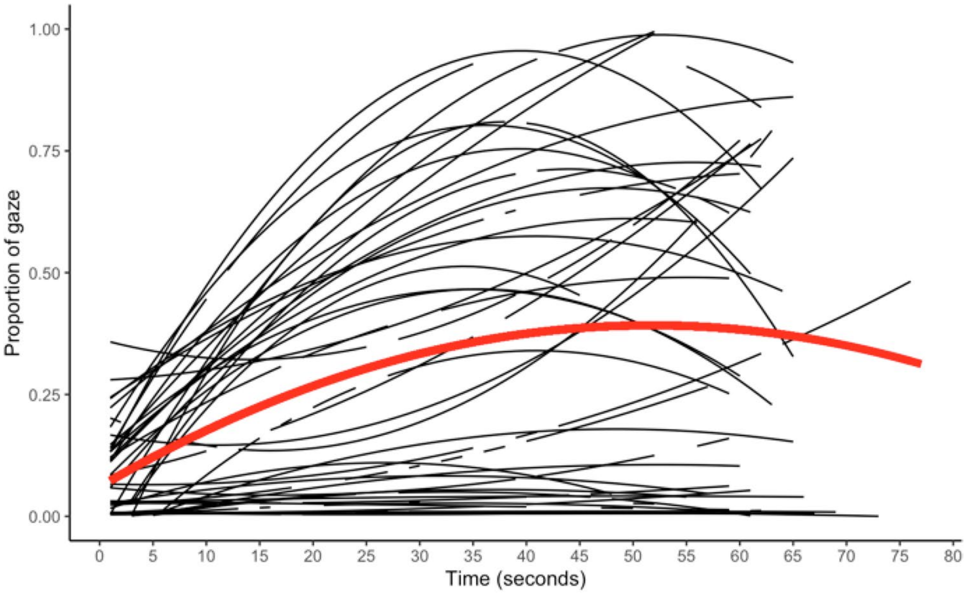
$$\text{Proportion of gaze to stranger}_{it} = \beta_{0i} + \beta_{1i}\text{time}_{it} + \beta_{2i}\text{times}q_{it} + e_{it}$$

Between-subjects

$$\beta_{0i} = \gamma_{00} + \gamma_{01}BI_i + u_{0i}$$

$$\beta_{1i} = \gamma_{10} + u_{1i}$$

Fig. 2 Plot showing quadratic trajectories of attention to the stranger's head/mask over the duration of the mask on portion of the episode. Average quadratic trajectory shown in red



$$\beta_{2i} = \gamma_{20} + \gamma_{21} BI_i + u_{2i}$$

Results

"Mask On" Model

For this conditional growth curve model, 2,601 observations were nested within 45 participants. We found a significant linear ($b = 0.01$, $p < 0.001$) and quadratic ($b < -0.001$, $p < 0.01$) main effect of time on proportion of gaze to the experimenter. Additionally, there was a significant main effect of BI ($b = 0.002$, $p = 0.04$), where children with higher levels of parent-reported BI showed persistently greater visual attention to the masked experimenter's head. There was no significant interaction with the quadratic time variable (Table 1, Fig. 4).

"Mask Off" Model

For this conditional growth curve model, 1,600 observations were nested within 45 participants. Again, we found a significant linear ($b = 0.03$, $p < 0.001$) and quadratic ($b < -0.01$, $p < 0.001$) main effect of time on proportion of gaze to the experimenter. Similar to the mask on model, there was a

Fig. 3 Plot showing quadratic trajectories of attention to the stranger's head/mask over the duration of the mask off portion of the episode. Average quadratic trajectory shown in red

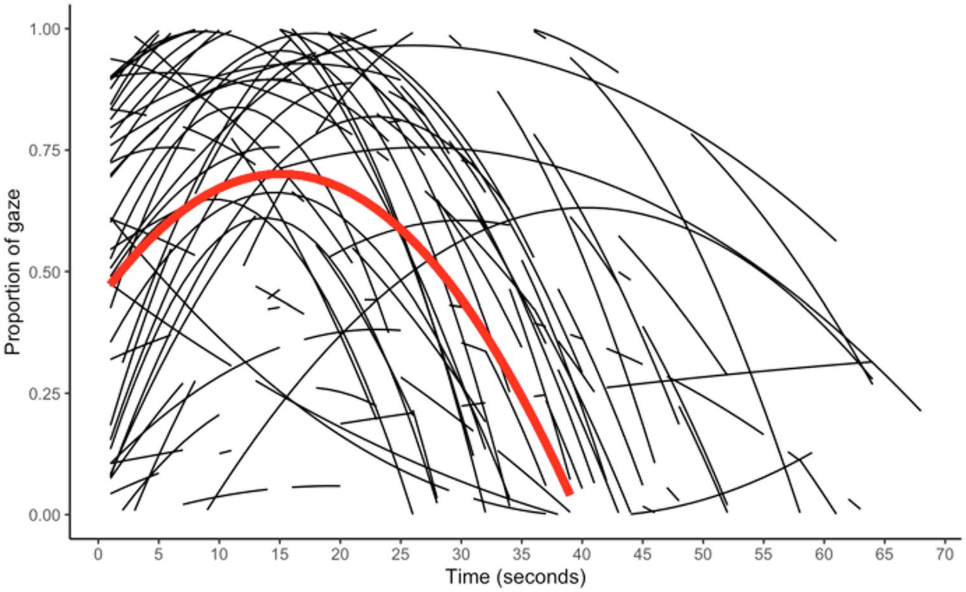


Table 1 Results from the quadratic growth curve models for the mask on phase of the task, with BI entered as a predictor

	Est	*SE*	*t*
Fixed effects			
Intercept	0.06*	0.03	2.50
Time	0.01***	0.003	4.47
Time squared	<-0.001**	<0.001	-2.89
BI	0.002*	0.001	2.16
BI × time squared	<0.001	<0.001	0.49
Random effects			
Intercept	0.12***		
Time	0.02***		
Time squared	<0.001***		
Residual	0.29		

Model based on 2,601 repeated measures of proportion of attention, nested within 45 persons

$^{*}p<0.05$; $^{**}p<.01$; $^{***}p<.001$

significant main effect of BI ($b=0.002$, $p=0.04$), where children with higher levels of parent-reported BI allocated greater visual attention to the experimenter's head and the mask that they had previously worn and removed. There was no significant interaction with the quadratic time variable (Table 2, Fig. 5).

Behavioral Data

Additionally, we tested whether BI was related to overt fear behavior during the episode, in line with Buss and colleagues (2013). For this analysis, we focused on (1) total duration spent expressing fear and (2) total duration spent maintaining a far distance from the experimenter, each divided by the total time of the task phase per child. We tested whether BI was significantly related to each of these behavioral metrics. Analyses were conducted for 44 of the 45 children included in the eye-tracking analysis, as one child was missing behavioral video. Here, we found that BI did not significantly relate to duration of fear expressed or proximity to the experimenter in either phase of the episode, with the exception of a significant negative relation between BI and the proportion of the episode spent maintaining a far proximity from the experimenter during the mask off phase ($b<-0.01$, $p=0.03$; Table 3).

We conducted additional analyses testing the association between average proportion of gaze to the experimenter during the mask on and mask off phases of the episode with the proportion of time spent expressing fear and maintaining a far distance from the experimenter. We found that average proportion of gaze to the stranger's masked face was significantly inversely related to the proportion of the episode spent maintaining a far proximity from the stranger during the mask on phase of the episode ($b=-0.18$, $p=0.03$). Otherwise, average gaze to the stranger was not significantly associated with either of these behavioral variables (Table 4).

Discussion

Attention biases to threat have been studied as a path to understanding the development of psychopathology, such as anxiety disorders (Gibb et al., 2015). This is particularly notable in linking attention bias to social threat and social anxiety disorder amongst children high in BI (Pérez-Edgar et al., 2010, 2011; Shackman et al., 2009; Szpunar & Young, 2012; White et al., 2017). However, research to date has

Fig. 4 Graph depicting proportion of gaze to the masked stranger's head/mask over time for low (−1 SD below mean), average, and high (+1 SD above mean) BI children

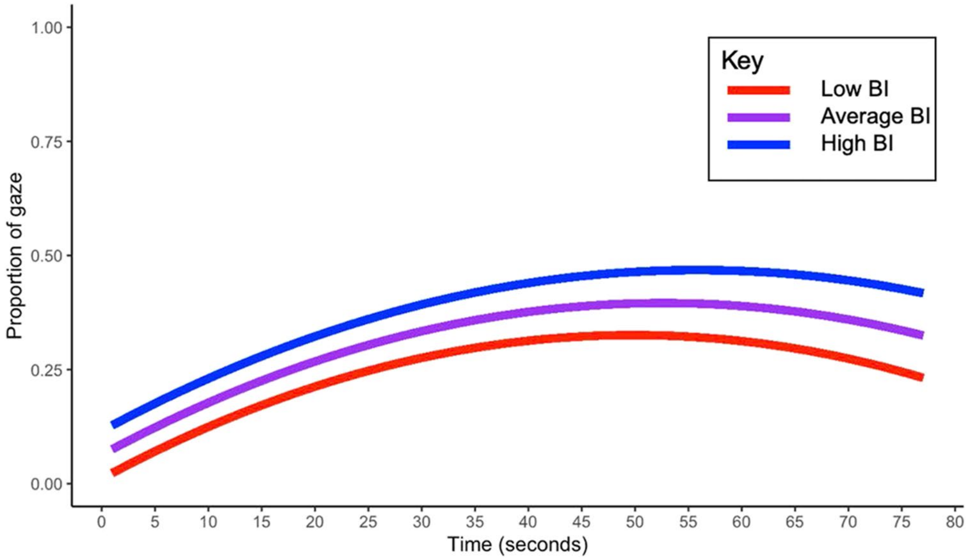


Table 2 Results from the quadratic growth curve models for the mask off phase of the task, with BI entered as a predictor

	Est	*SE*	*t*
Fixed effects			
Intercept	0.44***	0.06	7.03
Time	0.03***	0.006	6.18
Time squared	−0.001***	< 0.001	−7.53
BI	0.004*	0.002	2.12
BI × time squared	< −0.001	< 0.001	−0.94
Random effects			
Intercept	0.39***		
Time	0.03***		
Time squared	0.001***		
Residual	0.29		

Model based on 1,600 repeated measures of proportion of attention, nested within 45 persons

$^{*}p < 0.05$; $^{**}p < .01$; $^{***}p < .001$

been relatively narrow in scope, focusing on momentary presentations of static stimuli constrained to a computer screen. Moreover, research has predominantly focused on orienting to a threatening stimulus. Minimal work has investigated variability in individual attention patterns over time with shifts in purported threat levels. In this study, we used an ecologically valid paradigm exposing a child to a moderate threat, an individual in a gorilla mask, to examine variation in attention as a function of both threat level and BI.

In these analyses, we first tested the best model fit for trajectories of attention to the stranger during and after masking. Here, we found that a quadratic curve was the best fit for both phases of the episode. For each part of the episode, the proportion of gaze to the stranger first increased before decreasing, on average.

Additionally, we found a significant positive main effect of BI for the mask on model. As time elapsed while the gorilla mask was on, there was a persistent positive relation between BI and proportion of gaze to the stranger. This is in line with prior work finding an exaggerated response to threat and novelty for children high in BI (Shackman et al., 2009; Szpunar & Young, 2012). However, this finding also adds to a generally inconsistent line of work examining attention to threat in relation to social adaptation, especially in more naturalistic paradigms. For example, Gunther and colleagues (under review) found in an overlapping sample that a persistent avoidance of a female stranger, representing social novelty, was positively associated with greater internalizing problems, independent of the relation between BI and internalizing problems. The same study also found that the trajectory of attention to the stranger was not significantly related to BI (Gunther et al., under review). Gregory and colleagues (2019) found that high socially-anxious adults looked more at faces in the video than low socially-anxious adults while viewing a video of a social interaction, but only during the first two seconds of the video. Otherwise, their patterns of gaze were not significantly different. These differences across a variety of tasks suggest that patterns of attention to threat may be highly dependent on the context and nature of the threat, rather than a homogenous trait-level response to all potentially threatening cues.

Also consistent with our hypothesis, we found a significant positive main effect of BI for the mask off model. As in the mask on model, there was a positive relation between BI and proportion of gaze to the stranger. Prior research suggests that differences in a return to baseline attention may in part underlie differential risk for anxiety (Henderson & Wilson, 2017). As previously noted, increased attention to threat or novelty may potentiate negative affect. If a child continues to attend to a novel or threatening stimulus, even

Fig. 5 Graph depicting proportion of gaze to the stranger's head/mask over time for low (−1 SD below mean), average, and high (+1 SD above mean) BI children

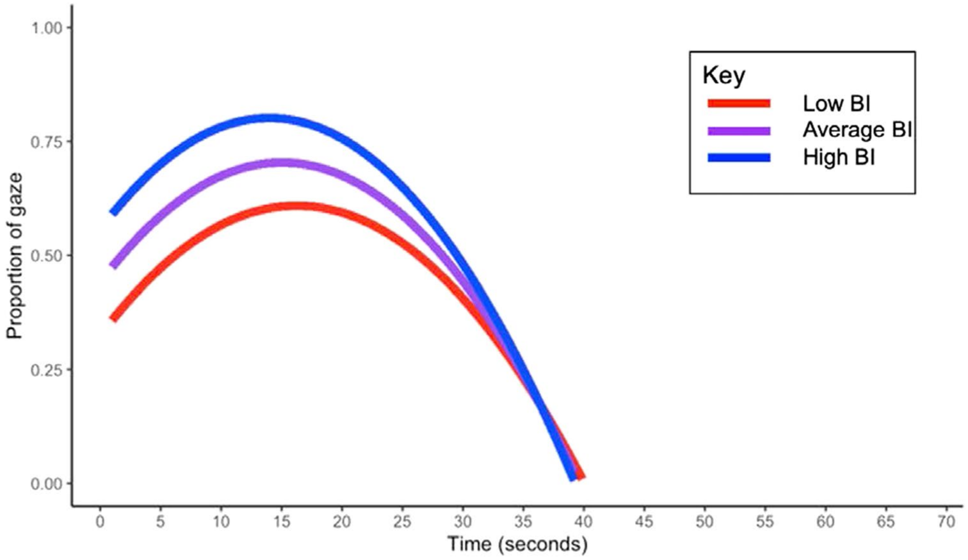


Table 3 Results from models testing associations between BI and behavioral measures of fear

	Mask on				Mask off			
	Fear duration proportion		Far proximity duration proportion		Fear duration proportion		Far proximity duration proportion	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	0.58**	0.17	0.95***	0.08	0.43	0.23	0.63***	0.11
BI	< 0.01	< 0.01	< 0.01	< 0.01	< 0.001	< 0.01	< −0.01*	< 0.01

$^{*}p<.05$; $^{**}p<.01$; $^{***}p<.001$

after the purported level of threat has declined, this may reflect processes limiting adaptive social engagement which may moderate risk for anxiety.

Finally, we found that while BI significantly related to proportion of gaze to the stranger over time during both the mask on and mask off phases of the episode, there were minimal relations between BI and our behavioral measures of fear. We found that level of BI was significantly related to the proportion of the episode spent maintaining a far proximity from the stranger, only during the mask off phase of the episode. In other words, children higher in BI spent less time far away from the stranger/more time closer to the stranger. This finding was not expected. Our findings relating BI and behavioral measures of fear partially replicated work by Buss and colleagues (2013) with this task, who found that fearful temperament did not predict fear expressed in the moment amongst a sample of kindergarteners in the same task. This study found that BI and non-BI children were not differentiated in their fear responses in high threat paradigms but rather only in low threat paradigms (Buss et al., 2013). Core features of the BI profile suggest that in the case of differences in behavior as a function of temperament, BI children would be likely to show physical avoidance of the perceived threat (Kagan et al., 1987; Rubin et al., 2002) rather than seeking physical proximity. However, all other relations between BI and fear behavior were not significant. Future work should further investigate differences in fear responses as a function of temperament and threat context.

Similarly, we found limited associations between average gaze to the experimenter and behavior. Average gaze to the stranger's head was significantly inversely related to the proportion of the episode spent maintaining a far distance from the stranger, only during the mask on phase. Children who allocated greater average attention to the masked stranger's head spent more time further away from the stranger. All other relations between average gaze to the stranger's head/mask and behavior were not significant.

This study was not without limitations. The scary mask task was the last of a series of "games" that children were asked to play during their visit to the laboratory. This task was the most emotionally arousing of the visit and was put last to minimize spillover into any subsequent tasks. However, that is not to negate the possibility of prior, less arousing tasks influencing behavior during the scary mask task. This task being the last of the visit also meant that the child was most familiar with the primary experimenter who accompanied them through the visit, and the masked experimenter was someone who they had briefly met during the stranger working task earlier in the visit. This increased familiarity with both the primary experimenter as well as the testing space may have mitigated some fear responses, especially for children high in BI who may show general reticence to novelty (Kagan et al., 1987; Rubin et al., 2002). Thus, the milieu of the task should be considered in contextualizing these findings.

Together, these findings suggest that naturalistic gaze may provide a more nuanced measure of individual responses than overt behavior alone. This nuance may be especially critical in characterizing children high in BI. Future work should examine the regulatory mechanisms that may underlie these differences in visual attention as compared to overt behavior, especially for children high in BI. Taken together, this work speaks to the richness of naturalistic eye tracking data, illustrating how microlongitudinal assessments of gaze over time may provide unique insights into attention patterns that may exacerbate developmental risk for anxiety.

Table 4 Results from models testing associations between proportion of gaze to the stranger's head/mask and behavioral measures of fear

	Mask on				Mask off			
	Fear duration proportion		Far proximity duration proportion		Fear duration proportion		Far proximity duration proportion	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	0.71***	0.07	1.02***	0.03	0.52**	0.15	0.47***	0.07
Gaze to stranger	0.04	0.18	−0.18*	0.08	−0.11	0.25	−0.15	0.12

$^{*}p<.05$; $^{**}p<.01$; $^{***}p<.001$

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Data Availability All data are available at https://osf.io/q2bz6/.

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