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Information Processing Biases in Behaviorally Inhibited Children: Response to Threat and Novelty

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Abstract

This study investigated selective attention to threat stimuli as a function of behaviorally inhibited temperament and stimuli familiarity. Forty children (ages 8–14) played a memory game in order to familiarize them with a set of faces depicted in photographs. These faces were later used along with novel faces in a pictorial dot probe task including novelty (familiar vs. novel) and threat (angry vs. neutral) conditions. BI was assessed using two self-report questionnaires. Children with BI exhibited an attentional bias towards threat, and they responded faster to unfamiliar faces across trials. There was no evidence for avoidance of threat following initial vigilance.

Keywords: behavioral inhibition; selective attention; vigilance; threat; novelty; dot probe

Behavioral inhibition (BI) is a temperament style characterized by a predisposition to become anxious or distressed in the face of novelty (Kagan, 1989). Approximately 15 to 20 percent of healthy toddlers are behaviorally inhibited (Kagan, 1997) and BI has been shown to have moderate stability throughout childhood (e.g., Kagan, Resnick, Snidman, Gibbons, & Johnson, 1988). As a group, children with BI have a considerably higher likelihood of developing anxiety disorders (Hirshfeld-Becker, Biederman, & Rosenbaum, 2004) as indicated by longitudinal (e.g., Biederman et al., 1993), familial (e.g. Rosenbaum et al., 1991), and retrospective studies (e.g., Reznick, Hegeman, Kaufman, Woods, & Jacobs, 1992). The mechanisms that place children with BI at higher risk for developing anxiety disorders, however, are not well understood. Lonigan and colleagues (e.g. Lonigan & Phillips, 2001; Lonigan, Vasey, Phillips, & Hazen, 2004) suggest that a

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potential mediator in the relationship between temperamental risk and anxiety is that children with BI may process information with a bias towards threat cues, similar to children diagnosed with an anxiety disorder (e.g. Vasey, Daleiden, Williams, & Brown, 1995) and adults (e.g. Vasey & Macleod, 2001).

Selective attention has been widely theorized to play an important role in emotion regulation and dysregulation (Lonigan & Phillips, 2001; Wilson & Gottman, 1996). People with a consistent attentional bias for signs of threat are thought to perceive the world as a dangerous place, and to expend more time and energy contemplating negative outcomes in favor of safety relevant information or engaging in alternative coping strategies. Thus, they experience increased anxiety. Although it is important to be alert and responsive to the threat in the face of real danger, the threshold at which individuals with anxiety interpret a stimulus as threatening and/or orient their attention to threat cues is lower (Wilson & MacLeod, 2003) and thus, their attentional processing may be less adaptive and potentially contributes to the development of psychopathology. Research on temperament provides an ideal opportunity to examine the attention-anxiety relationship (Shechner et al., 2012) and to do so within a developmental context as children with BI are at risk for developing anxiety disorders later in life.

Early studies examining attentional bias for threat in children with BI have yielded weak and inconsistent results (Kagan, Snidman, Zentner, & Peterson, 1999; Schwartz, Snidman, & Kagan, 1996). This may reflect methodological limitations as all of these studies have used the Stroop procedure, which has been criticized because cognitive interference on this task could be attributed to factors other than selective attention, such as emotional arousal (Williams, Watts, MacLeod, & Mathews, 1997). Another measure of attentional bias, the dot probe task, shown to be more sensitive in detecting attention to threatening information in anxious populations (Vasey & MacLeod, 2001), has only recently been used to assess attentional bias in children and adolescents with BI.

The dot probe procedure is a cueing paradigm that provides a direct test of attention allocation. Trials begin with a central fixation cross followed by two simultaneously displayed words or pictures reflecting different emotions (e.g., threatening versus neutral), commonly presented for 500 milliseconds (ms). A probe then appears unpredictably in the previous location of one of the words and remains on the screen until the participant identifies its location. Latencies to detect probes in the previous location of each type of stimuli are taken to reflect the attention allocated to the stimuli. Shorter latencies to detect probes in the same location as the previously presented threat word, for example, are interpreted as evidence of attention allocation to the threat word. Conversely, consistently longer latencies to detect probes appearing at the opposite location from a threat cue are interpreted as a result of attention being redirected from the position of the threat cue to the probe position. The dot probe task also allows attention allocation to be measured after stimuli have been presented for different time intervals, providing a means of examining the time course of attentional biases. Several studies suggest that an initial attentional bias for threat is followed by a purposeful avoidance of threat at longer stimulus intervals (Calvo & Avero, 2005; Koster, Verschuere, Crombez, & Damme, 2005; Rohner, 2002) with attentional bias for threatening stimuli reported in anxious individuals at 500 ms (Bradley, Mogg, & Miller, 2000; Koster et al. 2005; MacLeod, Mathews, & Tata, 1986; Mogg, Bradley, Miles, & Dixon, 2004). Stimuli are generally presented for longer intervals studies with children and biased attention has been observed after up to 1500 ms (e.g., Dalgleish, Taghavi, Neshat-Doost, Moradi, Canterbury, & Yule, 2003; Vasey et al., 1995; Vasey, El-Hag, & Daleiden, 1996). However, other research suggests that after ample time has been given for conscious and effortful strategies to be implemented, from roughly 1250 ms to 2000 ms, individuals with anxiety appear to avert their gaze from the location of the threat (Calvo & Avero, 2005; Koster et al., 2005; Rohner, 2002). This vigilant then avoidant response pattern has been hypothesized to contribute to the maintenance of anxiety as it prevents the individual from habituating to the fear- or anxiety-provoking stimuli (Koster et al., 2005).

To date, only a few studies have examined attentional bias in children with BI using the dot probe task. In one study, adolescents with a history of behavioral inhibition showed large attention biases to threat compared with adolescents without this history (Pérez-Edgar et al., 2010). Research with younger children with BI (age 5 years) showed a similar effect (Pérez-Edgar et al., 2011). Further, this study showed that early BI predicted later levels of social withdrawal only in children who showed a large bias toward threat in the dot probe task. The threat in this and similar studies was an angry face paired with either a neutral or happy face. Notably absent from this research is any examination of the association between attention bias to novelty and behavioral inhibition. This is surprising given that avoidance of novel experiences and events is a core feature of BI. Similar to individuals with anxiety disorders, inhibited children are highly sensitive to and typically avoid unfamiliar people and situations whether they seem objectively threatening or not (Cottraux, 2005). Schwartz and colleagues (2003) provide suggestive evidence for a differential response to the novel stimuli in children with BI. They looked at functional magnetic resonance imaging (*f*MRI) scans of adults who had been classified as toddlers as either BI or uninhibited, while they viewed novel and familiar faces. The BI group showed greater response in the amygdala, which has been implicated in fear, to the novel versus familiar stimuli compared to the uninhibited group (Schwartz, Wright, Shin, Kagan, & Rauch, 2003). It is possible that threat and novelty have a synergistic effect in terms of eliciting negative reactions from children with BI.

This study will assess high BI children's attentional processing patterns. These findings may add to our understanding of potential mechanisms associated with the characteristic reticence that often interferes with BI children’s participation in unfamiliar and/or social situations. Identifying potential information processing biases in children with BI will also contribute to our understanding of the etiology of anxiety disorders, which may have important implications for the prevention and treatment of these disorders.

Goals and Hypotheses

Given that BI is characterized by distress and avoidance of novelty and that it is known to be a risk factor for the development of anxiety disorders in children, we hypothesized the following:

1. Children high in BI will show preferential attention for threat cues.
2. Children high in BI will respond differentially to novel versus familiar social stimuli regardless of the affect portrayed.
3. Attentional bias in children high in BI will be heightened when stimuli are both

threatening and unfamiliar.

4. Initial vigilance for threat may be followed by avoidance in children high in BI.

Method

Participants

Forty-five children (24 males and 21 females) attending an educational summer day camp program in a university setting volunteered to participate in the study. All participants were between 8 and 14 years of age (*M* = 10.20, *SD* = 3.33). The participant sample was ethnically diverse and predominantly Caucasian and Asian which is representative of the surrounding sampling community. Consent for participation was obtained from the participants' parents, and assent for participation was obtained from the children.

Measures of BI

BI was measured using two self-report questionnaires assessing current levels of inhibition that are described below:

Behavioral Inhibition Scale (BIS) (Muris, Merckelbach, Wessel, & van de Ven, 1999). The BIS was developed as a potential alternative to laboratory observation of BI and has been administered to children and adolescents aged 11 through 18 years (e.g., Muris, Meesters, & Spinder, 2003; Muris, Merckelbach, Schmidt, Gadet, & Bogie, 2001; Muris et al., 1999). The BIS asks participants to rate themselves (on a 4-point scale) on four questions reflecting social features of BI including shyness, fearfulness, smiling, and ease of communication. The BIS has satisfactory internal consistency (α = 0.82; in our sample, α = 0.75) (Muris et al., 1999).

Modified Behavioral Inhibition Questionnaire (BIQ): (Bishop, Spence, & McDonald, 2003). The BIQ is a parent and teacher report measure of both social and nonsocial aspects of BI in young children. It was modified into a self-report measure for older children in the present study. One item was omitted because it was inappropriate for the sample age group. The remaining 29 of the original 30 items were reworded into self-report statements. For example, "Approaches new situations or activities very hesitantly" was changed to "I approach new situations or activities very hesitantly". The self-report form had adequate internal consistency within this study sample, yielding an alpha of 0.86.

Procedure

Children participated in groups of 10 to 15 in two sessions during their second week at summer camp. In the first session, children completed a face memory game, described in detail below. Two days later, they completed the BI questionnaires (BIS and BIQ) and the dot probe task. Questionnaires were read aloud and participants completed each question after it was read. After completing the questionnaires, each child was assigned to a computer where they independently completed the pictorial dot probe task. Please see below for a precise description of the dot probe task facial stimuli, procedure, and trials.

Experimental Tasks

Face stimuli memory game. Given that this study was designed to assess the effect of familiar versus unfamiliar information on information processing, a memory game was designed to familiarize participants with a subset of the pictorial face stimuli to be presented in the dot probe task. Four faces (two male and two female) were randomly selected from the Pictures of Facial Affect that were developed by Ekman and Friesen (1976) and were incorporated into the memory game. Participants were given an 8.5 x 11 inch sheet of paper with pictures of the faces randomly arranged on a 3 x 4 grid (12 pictures in total) consisting of each of the four stimuli faces displaying three emotions (neutral, happy, and angry). An empty 3 x 4 grid of identical size was also provided. The experimenter had individual pictures of each of the faces on the grid displaying all three affects on separate 8.5 x 11 inch sheets of paper. All sheets were placed face down in front of the experimenter and participants prior to beginning the game.

The experimenter explained to the participants that they would be playing a memory game with faces. They were then asked to turn over the face grid and told to try to memorize as many of the faces and their locations as possible. Participants were then asked to turn the pictorial grid face down and the empty grid face up. A picture of one of the faces was held up for 5 seconds (s) and participants were asked to mark down on the empty grid where that face had been displayed on the original grid. Participants were allowed to re-examine the original grid between face presentations. This procedure was repeated 12 times so that the participants had one chance to guess where each face was on the grid. The stimuli grids were presented for 25 s for the first four trials, 20 s for the middle four trials, and 15 s for the last four trials. The exposure time was reduced across trials as an attempt to minimize boredom because the children became more familiar with the faces throughout the course of the game. For the purposes of this experiment, stimuli were defined as novel/unfamiliar versus familiar based on the participants' total exposure time to the faces. From this point onward, the faces presented in the memory game will be referred to as familiar, and the faces presented in the dot probe task that were not part of the memory game as novel or unfamiliar.

Pictorial Dot Probe Task (MacLeod et al., 1986). Facial stimuli (as opposed to word stimuli) were used in the dot probe task to eliminate reading ability as a potential confound in response to the stimuli and because of previous research showing that the dot probe task with facial stimuli is a more sensitive measure of attentional bias (Pishyar, Harris, & Menzies, 2004).

Facial stimuli consisted of all the angry and neutral faces in the Pictures of Facial Affect developed by Ekman and Friesen (1976). These included two randomly selected female and two male faces randomly selected for use in the memory game (the familiar faces), and the remaining six female and four male faces from the set which were presented for the first time during the dot probe task (unfamiliar/novel faces). Analyses confirmed that the novel and familiar faces portrayed angry and neutral faces with equal clarity using Mazurski and Bond's (1993) comprehensive and updated norms concerning rater agreement for each of the emotional expressions portrayed in the Ekman and Friesen faces (familiar versus novel faces for either angry, $t(12) = 0.36$, $p = .73$, or neutral expressions, $t(12) = -1.68$, $p = 0.12$). Faces were displayed two at a time, horizontally across from each other on a computer screen. Each picture was 84 X 126 pixels in size and the pictures were separated by 132 pixels between them. An example of the stimuli used is provided in Figure 1.

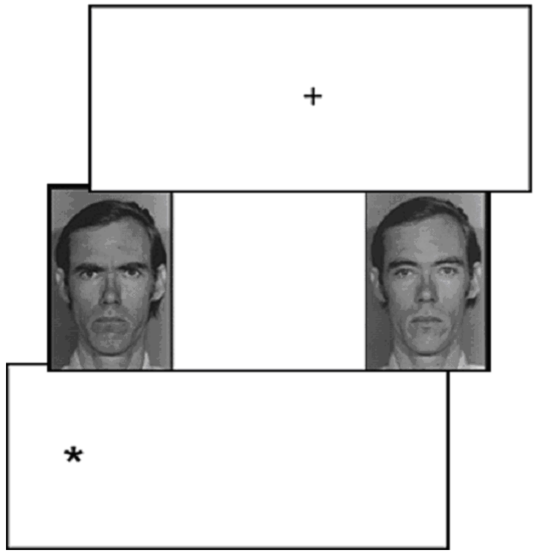

Figure 1. Example of stimuli used in dot probe trials with threatening and neutral faces (which are either novel or familiar) pitted against each other

Dot Probe Task Procedure and Trials. Children sat at separate computer workstations that were arranged around the perimeter of a classroom. Instructions introducing the task appeared on the computer screen. Following this, the participants completed 8 practice trials. The participants pressed any key to begin the task consisting of 40 experimental trials. Each trial began with a central fixation cross presented for 500 ms followed immediately by two photos of the same person (either novel or familiar) with two different emotional expressions (one threatening and one neutral) presented on the left and right sides of the screen. The order in which the different faces, expressions, and durations were presented was randomized across participants. The angry and neutral faces appeared an equal number of times on the left and right sides of the screen. In order to assess the possibility that an initial attentional bias for threat is followed by avoidance, half the trials presented faces for a short stimulus duration of 500 ms, and the other half presented them for a longer duration of 2000 ms. Trials were equally divided between familiar and unfamiliar faces (40 each). The 8 practice trials were identical in format to the experimental trials except that they included only familiar faces (each presented twice). Children were instructed to indicate where they saw the probe appear by pressing either the right or left arrow key (marked with yellow and green dots respectively) on a computer keyboard.

In the experimental trials the familiar faces were presented another five times (20 familiar trials) and the novel faces were presented twice (20 novel trials). Over the course of the experiment the unfamiliar faces had a total exposure time of 2.5 s (2500 ms) (each face was shown once at the 2000 ms interval and once at the 500 ms interval during the experiment). The familiar faces had a total exposure time of roughly 253 s (253,000 ms) to 255 s (254,500 ms) (slight variations occurred across individual face stimuli due to the nature of the memory game).

Results

Participants

Three of the 45 children who volunteered to participate in the study were excluded because they were rated by their camp counsellors as having difficulty understanding or communicating in English. Of the remaining 42 participants, 5 were identified as speaking English as their second language. In order to check whether all the participants understood the tasks, questionnaires were checked for inconsistent responding (questionnaire responses were deemed invalid if more than two contradictory answers were endorsed on the BIS or more than three contradictory answers were endorsed on the BIQ), and the number of inaccurate responses on the dot probe task was examined (subjects were excluded if they made inaccurate responses on the dot probe task more than 25% of the time). All participants showed acceptable consistency on questionnaire responses but two participants who had unacceptably high levels of inaccurate responses (inaccurate trials > 68%; for all remaining participants inaccurate trials < 10%) were excluded from analyses. Thus, analyses were conducted using the data from 40 participants (21 males and 19 females).

Relationships between Measures

The correspondence between the two self-report BI measures (BIS and the BIQ) was examined using Pearson correlation and found to be significant (r (40) = 0.55, p = .001). Some variation in scores on these measures was expected because the version of the BIS used only assesses the social aspects of BI, whereas the BIQ assesses BI across contexts. Therefore, the correlation obtained between the BIQ and BIS was judged to be satisfactory.

Questionnaire Standardization and Combination

In order to classify children as high or low BI, their ratings on both the BIS and the BIQ were combined into a single score. The BIS and BIQ were standardized so that they were on the same scale and participants' scores on these two measures could be combined with equal weighing. The standardization sample consisted of 228 children who attended the same recreational camps across two seasons (including the 40 children who participated in the present study). All participants in the standardization sample were between ages 7 and 14 years, and there were an approximately equal number of males (48%) and females (52%). Each participant's raw scores on the BIS and on the BIQ were converted into *z*-scores based on the means and standard deviations from the standardization sample. These *z*-scores were converted into *t*-scores to enhance interpretive clarity by removing the negative values and decimals inherent in the calculated *z*-scores. In order to yield a BI total T score for each child, their *t*-scores on the BIQ and the BIS were combined and averaged.

Group Characteristics

The children were divided into low and high BI groups based on a median split of the BI total T scores. Therefore, when children are described as high or low BI, this refers to where they scored relative to other children in the sample based on their BI total T-score. The boundary dividing the two groups was T = 48. The low BI group (n = 20, M BI total T score = 39.81, SD = 6.08) consisted of 10 males and 10 females with a mean age of 10.40 (SD = 2.93). The high BI group (n = 20, M BI total T score = 54.38, SD = 6.15) consisted of 11 males and 9 females with a mean age of 10.05 (SD = 3.82). The two groups differed significantly in their self-endorsed BI, $t(38) = -7.71$, $p < .001$. High and Low BI group raw scores on the BIQ and the BIS that were standardized and then combined are presented in Table 1.

Table 1

Raw Behavioral Inhibition Scale (BIS) and Behavior Inhibition Questionnaire (BIQ) Scores Before Transformation by Group (High Versus Low Behavioral Inhibition)

	Group			
	High BI (n = 20)		Low BI (n = 20)	
Raw questionnaire score	*M*	*SD*	*M*	*SD*
Behavioral inhibition scale	12.25	1.99	8.25	2.33
Behavioral inhibition questionnaire	125.85	16.78	88.65	21.13

Preparation of the RT Data

In keeping with standard practice in dot probe tasks, only correct trials were included in the analyses. Errors occurred on 3.84% of trials and these were eliminated from the data. Further, to minimize the influence of extreme outliers, all RTs of less than 100 ms and greater than 3000 ms were removed. Each participant's data was also examined for outliers using box-and-whisker plots, and RTs greater than 3 SD from the participant's mean were removed. In total, 2.20% of the data was identified as extreme outliers and discarded.

Face Stimuli Characteristics: Gender Effects

A 2 x 2 mixed design ANOVA, with participant gender as the between-subjects variable and face stimuli gender as the within-subjects variable, was performed to rule out the possibility that the gender of the face stimuli affected participant responses on the dot probe task. The gender of the face stimuli was not significantly related to RTs, $F(1, 38) = 0.18$, $p = .67$, and the gender of the face stimuli did not significantly interact with the gender of the participant, $F(1, 38) = 0.00$, $p = .99$.

Participant Gender and Age Analyses

Potential gender differences in self-reported BI were examined using a t-test. Males and females were not found to vary in BI total T scores, $t(38) = 0.13$, $p = .90$. Males' and females' dot probe performances were also compared using an ANOVA with gender as the between-subjects variable, and RTs based on face familiarity (novel vs. familiar), emotional expression (threatening vs. neutral), and duration of stimulus presentation (500 ms vs. 2000 ms) as the dependent variables. Gender was not significantly related to overall RT, $F(1, 39) = 0.16$, $p = .70$. Gender also did not significantly interact with responses to emotional expression, $F(1, 39) = 0.03$, $p = .86$, face familiarity, $F(1, 39) = < .001$, $p = .98$, or the duration of the stimulus presentation, $F(1, 39) = 0.72$, $p = .40$. Given that the participants' gender did not influence any of the dependent variables, it will not be considered in the subsequent analyses.

Potential age effects were examined using a series of bivariate Pearson correlations. Age was preserved as a continuous variable and response biases related to emotional expression and face familiarity were defined as continuous variables based on RT differences between responses to threat trials compared to neutral trials and novel trials compared to familiar trials respectively. Specifically, to examine the effects of threat, each participant's median RT when the probe followed threatening faces was subtracted from their median RT when probes followed neutral faces. Thus, positive values indicate an attentional bias for threat. This procedure was repeated for novel and familiar face pairs RT. In this case, positive scores would indicate faster responses to trials with novel faces. The obtained difference values will be referred to as threat bias scores and novelty bias scores from this point on. Participants' age did not influence threat bias scores, $r(40) = -.06$, $p = .73$, or novelty bias, $r(40) = -.04$, $p = .82$. Similarly, age was not significantly related to BI, $r(40) = .09$, $p = .58$. Age was significantly negatively related to overall RT averaged across conditions, $r(40) = -.33$, $p = .04$. Given that age is unrelated to BI or the dependent variables of interest it will not be considered in the following analyses.

Response to Threat and Novelty

High and low BI children's RT means and standard deviations for all dot probe conditions are presented in Table 2.

Table 2
Mean of Participants' Median RTs (ms) as a Function of BI Group, Threat, Stimulus Duration, and Face Familiarity

	Group			
	High BI (n = 20)		Low BI (n = 20)	
Condition	*M*	*SD*	*M*	*SD*
Emotion Preceding Probe				
Threatening	489.30	100.49	473.93	100.24
Neutral	508.65	138.53	466.31	87.76
Stimulus duration				
500 ms	509.72	132.24	488.61	112.57
2000 ms	488.23	112.57	451.63	75.18
Face stimuli				
Unfamiliar	493.31	106.68	475.77	103.83
Familiar	504.64	132.34	464.47	84.36

Median RTs were calculated for each subject and condition and entered into a 2 x 2 x 2 x 2 mixed design ANOVA. There was one between-subjects variable of BI (high vs. low) and three within-subjects variables including face familiarity (novel vs. familiar), emotional expression (threatening vs. neutral), and duration of stimulus presentation (500 ms vs. 2000 ms). The only significant main effect was for the duration of stimulus presentation. Overall, participants responded faster to the probe when it appeared following a stimulus presentation of 2000 ms compared to 500 ms $F(1, 38) = 10.06$, $p = .003$.

As hypothesized, the interaction between BI and emotional expression was significant, $F(1, 38) = 4.19$, $p = .048$, $h_p^2 = .10$, indicating that children with high and low BI are differentially affected by threatening stimuli. An examination of the plot of this interaction (see Figure 2) shows that children high in BI responded faster to probes preceded by threatening faces compared to probes preceded by neutral faces, whereas children with low BI showed the opposite tendency with a smaller RT difference.

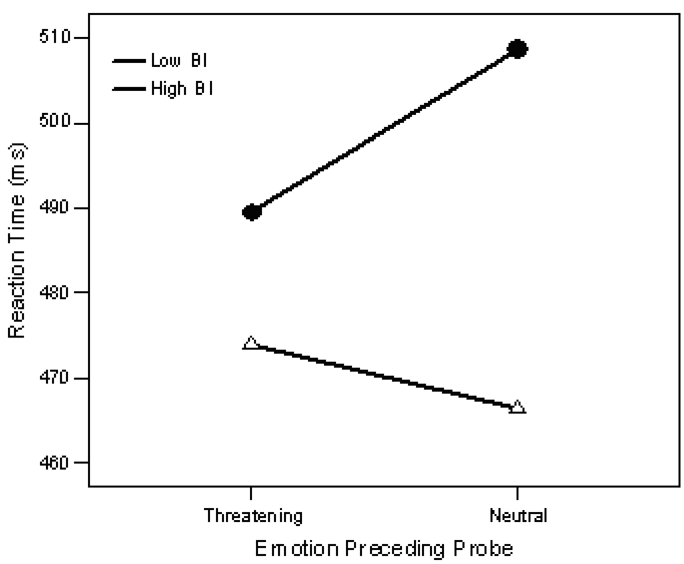

Figure 2. Graph illustrating the significant interaction between BI and response to probes following threatening or neutral faces.

Given this significant interaction, follow-up paired samples *t*-tests using Bonferroni corrections were conducted separately for the BI groups to assess within-group differences. The magnitude of the differences in RTs for probes following threatening versus neutral faces was not significant within the high BI, $t(19) = 1.57$, $p = .13$, or low BI, $t(19) = 0.10$, $p = .92$ groups.

To assess whether participants' attention to threat varied across the two stimulus durations, the interaction between emotional expression and duration of stimulus presentation was assessed. It was not significant, $F(1, 38) = 1.10$, $p = .30$. The three-way interaction between BI group, emotional expression, and duration was also not significant, $F(1, 38) = 0.001$, $p = .97$. This lack of significant interactions suggests that BI children's responses to threat did not differ depending on the duration of stimulus presentation; therefore, no follow-up analyses concerning duration were conducted.

An examination of the interaction between emotional expression and face familiarity revealed that response to threat was not influenced by the novelty of the face pair, $F(1, 38) = 0.44$, $p = .51$. However, the interaction between BI and face familiarity was significant, $F(1, 38) = 4.51$, $p = .04$, $h_p^2 = .11$, indicating that level of BI influenced responses to novel and familiar faces across trials. The plot of this interaction (see Figure 3) shows that children high in BI responded faster to novel faces than to familiar faces, and children with low BI conversely responded faster to familiar than novel faces.

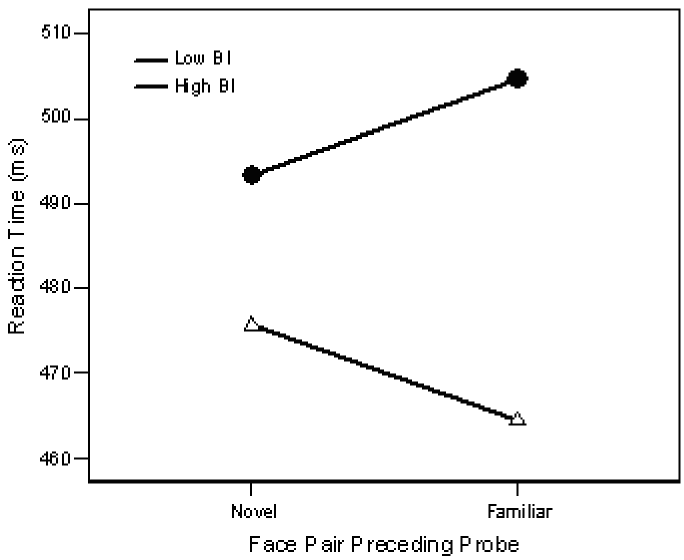

Figure 3. Graph illustrating the significant interaction between BI and response to probes following unfamiliar or familiar face pairs across trials.

Using follow-up Bonferroni corrected paired samples *t*-tests, the difference in RTs to probes following novel versus familiar face pairs was not significant within the high BI group, $t(19) = 1.49$, $p = .15$, but there was a trend for the low BI group to respond faster to the familiar faces, $t(19) = -1.86$, $p = .08$.

Discussion

Before discussing the findings of this study, the specifics of the dot probe task used have important implications for the results and are worthy of discussion. Given that participants had repeated exposure to the familiar but not the novel faces, a potential concern is that differential practice with the familiar than novel faces may have influenced performance on the task. It is important to note, however, that the participants did not make any response based on the faces presented. Rather, following the faces, a probe appeared unpredictably in the previous location of one of the faces. Practice responding to the probe (as opposed to the faces) would be expected to affect RTs on the task. Thus, while the possibility of an indirect practice effect related to the faces is difficult to rule out, there is no theoretical reason to believe that children with high and low BI would obtain differential benefit from practice. Therefore, any unanticipated practice effects should not influence the results of interest related to group differences.

A second characteristic of the dot probe task concerns the repetition of the novel faces as each novel face was presented twice during the experimental task. The decision to repeat the novel faces was made after weighing practical and methodological considerations. It was important to use a facial stimuli set that was well validated and widely used, and which provided excellent examples of angry and neutral expressions. The Ekman and Friesen *Pictures of facial affect* (1976) were chosen based on these factors. Unfortunately for our purposes, this stimulus set only shows 14 models portraying angry and neutral affects. Four of these faces were randomly selected to be included in the memory game (the familiar faces), leaving only 10 novel faces. Ideally these novel faces would only be shown once during the course of the dot probe task so that they would be truly novel to the participants. However, this would leave only 10 trials assessing the effects of novelty, which would have raised concerns about the reliability of the observations. The decision to use the Ekman and Friesen stimuli and repeat the novel faces provided a compromise between concerns related to the quality of the facial stimuli used and the reliability of observations on the dot probe task. The repeated exposure to the novel faces may, therefore, have made it more difficult to find effects due to novelty, as we assessed responses to familiar stimuli versus relatively novel stimuli (as opposed to entirely novel stimuli) as defined by the participants total exposure time to the faces. Despite this potential limitation, the results of this study did reveal interesting differences between high and low BI groups and these are discussed below.

Although the differences in responses to threatening versus neutral faces were not significant within BI groups, the between group results indicate that children with high self-rated BI are more likely to attend to threatening facial expressions than children with low self-rated BI. These results are similar to those reported by Pérez-Edgar et al., (2010, 2011) and suggests that children with high BI may process information in a similar way to anxious children. These findings are consistent with information processing theories that posit that attentional bias precedes clinical anxiety, rather than simply being a symptom of it. This adds to our understanding of the possible mechanisms underlying the relationship between BI and anxiety disorders. Specifically children with high BI’s greater tendency to focus on threatening information in their environment may lead to exaggerated perceptions of the danger and may trigger and maintain a heightened state of arousal and could contribute to the development of anxiety symptoms. Focusing on potential cues to threat may also take away from processing resources that would otherwise be available to engage in more constructive coping, which theoretically would serve to further exacerbate and maintain inhibition and anxiety.

All children responded faster to probes following faces that were presented for longer durations independent of their level of BI, or the novelty or emotional expression of the face presented. Perhaps the longer stimulus presentation gave the children more time to prepare to respond to the probe, resulting in faster overall RTs in this condition. Contrary to expectations, the display time for faces was not related to responses to threat or novelty. Thus, there was no evidence that this initial focus on threat is followed by avoidance of the threatening stimuli. The absence of avoidance could be related to the fact that the participants in this study were children, and their strategic control of attention is still developing. This explanation seems unlikely, however, because age was not related to attentional biases at either stimulus duration interval. Therefore, at least over the stimulus durations used in this study (500 ms and 2000 ms), it did not appear that children with high BI attempted to regulate their emotional experience using attentional avoidance of threat. Alternatively, it is possible that avoidance may eventually occur. The studies that have found avoidance in anxious adults have found it generally occurs before 2000 ms (Calvo & Avero, 2005; Koster et al., 2005; Rohner, 2002); however this may not have been long enough to observe this effect in children. This possibility should be explored in future research.

The pattern of attentional biases for threat was the same for both novel and familiar faces regardless of whether the children were high or low in BI. Thus, the hypothesis that threat and novelty would have a synergistic effect in eliciting vigilance was not supported. In line with our expectations, the high and low BI groups responded differently to stimuli that were novel across trials. Children high in BI tended to respond faster to the unfamiliar stimuli across trials, whereas the group of children who were low in BI showed the opposite pattern with faster RTs to the familiar face pairs, but these differences were not significant within groups.

These results could be interpreted in several ways. The low BI group’s faster responses to probes following familiar face pairs could be taken as evidence of habituation. Specifically, processing faces after repeated previous exposure may take up less cognitive resources so participants have more resources available to prepare for the subsequent probes and respond to them as soon as they appear. Processing unfamiliar faces may require more cognitive resources that would not immediately become available the moment the face pairs disappear, which results in a lag in responding to the subsequent probes. However, the high BI group’s results do not fit with this explanation showing no evidence of habituation to familiar faces. The responses of children high in BI were faster to unfamiliar stimuli, which seemed to increase their alertness or readiness to respond. This finding suggests that unfamiliar stimuli are particularly salient for children high in BI from an information processing perspective. Future research is needed to clarify these findings.

This is the first time response to novelty has been explored in an information processing task with individuals high in BI, and these findings indicate that this is an important area to follow up in future research. In particular, it would be valuable to assess if children with high BI would also have faster responses to novelty if novel stimuli were pitted against familiar stimuli in a task such as the dot probe, so that they had to compete for attentional resources. It could be that children with high BI process threat and novelty in a similar way, and that vigilance for unknown stimuli is also associated with vulnerability to anxiety. Certainly, it is clear that for children with high BI, as well as persons with social phobia, both novelty and threat are capable of eliciting similar behavioral responses (Cottraux, 2005).

A caveat to the conclusions and interpretations that can be reached from the findings of this study is that it is possible that the high BI group also contained some children who had anxiety symptoms. There is debate in the field concerning the conceptual relations between BI temperament and anxiety symptomatology and how researchers should grapple with the points of convergence between these constructs (Frick, 2004). Evidence supports the notion that BI and anxiety are distinct constructs that share some overlapping components. Specifically, BI is a temperament style that refers to a range of normative characteristics, is more prevalent than anxiety in the population, is neither necessary nor sufficient for the development of anxiety, and is not necessarily associated with dysfunction (Biederman et al., 1990). Anxiety disorder refers to a narrower cluster of symptoms that are excessive and maladaptive, and interfere with the affected individual's functioning. Nevertheless, particularly at the extreme end of BI temperament, BI and anxiety share a number of characteristics such as fearfulness, reticence, and a cautious approach to uncertainty. This is perhaps reflected in BI measures correlations with anxiety scales (e.g., Muris et al., 1999). If our high BI sample contained a high proportion of anxious children, then our findings related to attentional biases for threat would not add much to the literature as it has already been established that anxious children show an attentional bias for threatening cues (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). However, this is unlikely to be the case given the way in which our sample was obtained and categorized. Specifically, the participants represented the full range of children attending a summer camp, there was no pre-selection procedure for high or low BI, and the children were put into groups on the basis of a median split. One could argue that it would be desirable to ensure that anxiety did not influence our results by using procedures such as measuring anxiety and partialling it out. However, we wanted to assess the full spectrum of BI temperament and believe that attempting to eliminate any anxiety from the way BI is defined may pose a threat to construct and content validity given that BI and anxiety overlap conceptually. By choosing a typical sample of children from the community and assessing variability in BI on a continuum, our findings contribute to the field by speaking to the generalizability of an attentional preference for threat. Our results show that preferential processing of threat cues is not specific to anxious populations and can be found within the normal range of temperament differences. Furthermore, other theoretically relevant stimuli characteristics may prove to elicit biases in information processing, such as novelty. In order to better understand the links between BI and anxiety and the role of biased attention, future research may examine attentional biases individually in a longitudinal design. This would provide insight into how different attentional preferences relate to the development of clinical levels of anxiety.

Other limitations to the present study relate to the small sample size and the BI measures used. Given that only 40 children participated in the study, statistical power to detect effects was somewhat low, and BI groups were formed using a median split in order to ensure there were enough participants per group. Although median splits are popularly used in research (e.g. Mogg, Bradley, de Bono, & Painter, 1997; Mogg et al., 2000; Rohner, 2002) it is not an ideal method for dividing groups. Although there are generally significant differences between the groups formed, the participants close to the median do not truly differ from each other. This results in reduced sensitivity to detect differences associated with the grouping variable. In the present study, the small sample size and use of a median split may account for the insignificant within-group findings, as several of the RT differences were quite large. For instance, Yiend and Mathews (2004) reported that in past research the differences in RTs to threatening versus neutral stimuli are generally 10 ms to 20 ms, and in this study the high BI group responded 19.24 ms faster to threatening faces than neutral faces.

Finally, our use of the BIQ as a self-report form has not been reported in previous research. Although research on the parent and teacher forms of the BIQ has demonstrated adequate psychometric properties (Bishop et al., 2003), it cannot be assumed that this also applies to the self-report form.

With these caveats in mind, the results of the present study suggest that this is a valuable area to follow up in future research. Further exploration of attentional biases of BI children may not only help us to understand the mechanisms that link BI temperament to clinical anxiety but could also potentially provide avenues for preventing these disorders.

References

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), 1–24.

Biederman, J., Rosenbaum, J. F., Bolduc-Murphy, E. A., Farone, S. V., Chaloff, J., Hirshfeld, D.R., et al. (1993). A 3-year follow-up of children with and without behavioral inhibition. *Journal of the American Academy of Child and Adolescent Psychiatry, 32*(4), 814–821.

Biederman, J., Rosenbaum, J. F., Hirshfeld, D. R., Farone, S. V., Bolduc, E. A., Gersten, M., et al. (1990). Psychiatric correlates of behavioral inhibition in young children of parents with and without psychiatric disorders. *Archives of General Psychiatry, 47*, 21–26.

Bishop, G., Spence, S. H., & McDonald, C. (2003). Can parents and teachers provide a reliable and valid report of behavioral inhibition? *Child Development, 74*(6), 1899–1917.

Bradley, B. P., Mogg, K., & Millar, N. H. (2000). Covert and overt orienting of attention to emotional faces in anxiety. *Cognition and Emotion, 14*(6), 789-808.

Calvo, M. G., & Avero, P. (2005). Time course of attentional bias to emotional scenes in anxiety: Gaze direction and duration. *Cognition and Emotion, 19*(3), 433–451.

Cottraux, J. (2005). Recent developments in research and treatment for social phobia (social anxiety disorder). *Current Opinion in Psychiatry, 18*(1), 51–54.

Dalgleish, T., Taghavi, R., Neshat-Doost, H., Moradi, A., Canterbury, R., & Yule, W. (2003). Patterns of processing bias for emotional information across clinical disorder: 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*, 10–21.

Ekman, P., & Friesen, W. V. (1976).). *Pictures of facial affect*. Palo Alto, CA: Consulting Psychologists Press.

Frick, P. J. (2004). Integrating research on temperament and childhood psychopathology: Its pitfalls and promise. *Journal of Clinical Child and Adolescent Psychology, 33*(1), 2–7.

Hirshfeld-Becker, D. R., Biederman, J., & Rosenbaum, J. F. (2004). Behavioral inhibition. In T. L. Morris & J. S. March (Eds.), *Anxiety disorders in children and adolescents* (2nd ed., pp. 27–58). New York, NY: Guilford Press.

Kagan, J. (1989). Temperamental contributions to social behavior. *American Psychologist*, *44*(4), 668–674.

Kagan, J. (1997). Temperament and reactions to unfamiliarity. *Child Development, 68*, 139–143.

Kagan, J., Reznick, J. S., Snidman, N., Gibbons, J., & Johnson, M. O. (1988). Childhood derivatives of inhibition and lack of inhibition to the unfamiliar. *Child Development*, *59*(6), 1580–1589.

Kagan, J., Snidman, N., Zentner, M., & Peterson, E. (1999). Infant temperament and anxious symptoms in school age children. *Development and Psychopathology, 11*, 209–224.

Koster, E. H., Verschuere, B., Crombez, G., & Damme, S. V. (2005). Time-course of attention for threatening pictures in high and low trait anxiety. *Behaviour Research and Therapy, 43*, 1087–1098.

Lonigan, C. J., & Phillips, B. M. (2001). Temperamental influences on the development of anxiety disorders. In M. W. Vasey & M. R. Dadds (Eds.), *Developmental psychopathology* of *anxiety* (pp. 60–91). London: Oxford University Press.

Lonigan, C. J., Vasey, M. W., Phillips, B. M., & Hazen, R. A. (2004). Temperament, anxiety, and the processing of threat-relevant stimuli. *Journal of Clinical Child and Adolescent Psychology*, *33*(1), 8–20.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*, 15–20.

Mazurski, E. J., & Bond, N. W. (1993). A new series of slides depicting facial expressions of affect: A comparison with the pictures of facial affect series. *Australian Journal of Psychology, 45*(1), 41–47.

Mogg, K., Bradley, B. P., de Bono, J., & Painter, M. (1997). Time course of attentional bias for threat information in non-clinical anxiety. *Behaviour Research and Therapy, 35*, 297–303.

Mogg, K., Bradley, B. P., Miles, F., & Dixon, R. (2004). Time course of attentional bias for threat scenes: Testing the vigilance-avoidance hypothesis. *Cognition and Emotion*, *18*(5), 689–700.

Mogg, K., McNamara, J., Powys, M., Rawlinson, H., Seiffer, A., & Bradley, B. P. (2000). Selective attention to threat: A test of two cognitive models of anxiety. *Cognition and Emotion, 14,* 339–375.

Muris, P., Meesters, C., & Spinder, M. (2003). Relationships between child- and parent-reported behavioural inhibition and symptoms of anxiety and depression in normal adolescents. *Personality and Individual Differences, 34*(5), 759–771.

Muris, P., Merckelbach, H., Schmidt, H., Gadet, B., & Bogie, N. (2001). Anxiety and depression as correlates of self-reported behavioural inhibition in normal adolescents. *Behaviour Research and Therapy*, *39*, 1051–1061.

Muris, P., Merckelbach, H., Wessel, I., & van de Ven, M. (1999). Psychopathological correlates of self-reported behavioural inhibition in normal children. *Behaviour Research and Therapy, 37,* 575–584.

Pérez-Edgar, K., Reeb-Sutherland, B., McDermott, J., White, L., Henderson, H., Degnan, K. . . . Fox, N. (2011). Attention biases to threat link behavioral inhibition to social withdrawal over time in very young children. *Journal of Abnormal Child Psychology, 39,* 885-895.

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*, 349-357.

Pishyar, R., Harris, L. M., & Menzies, R. G. (2004). Attentional bias for words and faces in social anxiety. *Anxiety, Stress, and Coping, 17*(1), 23–36.

Reznick, J. S., Hegeman, I. M., Kaufman, E., Woods, S. W., & Jacobs, M. (1992). Retrospective and concurrent self-reports of behavioral inhibition and their relation to adult mental health. *Development and Psychopathology, 4*, 301–321.

Rohner, J. (2002). The time-course of visual threat processing: High trait anxious individuals eventually avert their gaze from angry faces. *Cognition and Emotion, 16*, 837-844.

Rosenbaum, J. F., Biederman, J., Hirshfeld, D. R., Faraone, S. V., Bolduc, E. A., Kagan, J., et al. (1991). Further evidence of an association between behavioral inhibition and anxiety disorders: Results from a family study of children from a non-clinical sample. *Journal of Psychiatric Research, 25*, 49–65.

Schwartz, C. E., Snidman, N., & Kagan, J. (1996). Early temperamental predictors of stroop interference to threatening information at adolescence. *Journal of Anxiety Disorders, 10*(2), 89–96.

Schwartz, C. E., Wright, C. I., Shin, L. M., Kagan, J., & Rauch, S. L. (2003). Inhibited and uninhibited infants "grown up": Adult amygdalar response to novelty. *Science, 300*, 1952–1953.

Shechner, T., Britton, J., Pérez-Edgar, K., Bar-Haim, Y., Ernst, M., Fox, N. . . . Pine, D. (2012). Attention biases, anxiety, and development: Toward or away from threats or rewards? *Depression and Anxiety, 29*: 282-294.

Vasey, M. W., & Macleod, C. (2001). Information-processing factors in childhood anxiety: A review and developmental perspective. In: M. W. Vasey & M. R. Dadds (Eds.), *Developmental psychopathology of anxiety* (pp. 253–277). London: Oxford University Press.

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,* 267–279.

Vasey, M. W., El-Hag, N., & Daleiden, E. L. (1996). Anxiety and the processing of emotionally threatening stimuli: Distinctive patterns of selective attention among high- and low-test-anxious children. *Child Development, 67,* 1173–1185.

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1997). *Cognitive psychology and emotional disorders* (2nd ed.). New York: Wiley.

Wilson, B. J., & Gottman, J. M. (1996). Attention—the shuttle between emotion and cognition: Risk, resiliency and physiological bases. In E. M. Hetherington & E. A. Blechman (Eds.), *Stress, coping and resiliency in children and families* (pp. 189–228). Hillsdale, NJ: Lawrence Erlbaum Associates.

Wilson, E., & Maclead, C. (2003). Contrasting two accounts of anxiety-linked attention bias: Selective attention to varying levels of stimulus threat intensity. *Journal of Abnormal Psychology, 112*(2), 212–218.

Yiend, J., & Mathews, A. (2001). Anxiety and attention to threatening pictures. *The Quarterly Journal of Experimental Psychology, 54*(3), 665-681.

Yiend, J., & Mathews, A. (2004). Selective attention tasks in clinical research. In A. Wenzel, & D. C. Rubin (Eds.), *Cognitive methods and their application to clinical research* (pp. 97–117). Washington, DC: American Psychological Association.