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THE ROLE OF ATTENTION BIAS AND BEHAVIORAL INHIBITION IN PREDICITING CHILDREN'S SOCIAL ANXIETY

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ABSTRACT

Behavioral inhibition (BI) in children is a temperament trait commonly linked with social anxiety and attention bias to threat. Many studies in the past have critically investigated the intricate processes which link these elements together. One way to study the relation between BI, attention bias, and social anxiety in particular, is through ERP data. In this study, children ages 9-12 were presented with neutral and facial stimuli followed by a target in either the same location or the opposite location of the face stimulus as part of an affective Posner task. ERP components, specifically N1, N2, P2, and P3, were tracked in order to determine possible differences in temperament, electrophysiological markers, and salience sensitivity between BI and non-BI children. Results indicated a larger validity effected among BI children indicating difficulty in shifting attention. N1 and N2 amplitudes were associated with orientating attention and attention control, respectively. The validity effect by N2 interaction found that augmented N2 amplitudes demonstrated stronger relations between the validity effect and social anxiety impacted by an inability to defer attention away from threatening facial stimuli. P3 amplitudes were linked to resource allocation and certainty of the presented task such that smaller P3 amplitudes indicated greater BI and greater social anxiety. The findings suggest that changes in EEG amplitudes reflect the processes supporting the link between BI, attention bias, and social anxiety.

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Chapter 1

Introduction

Every minute of every day our brains are constantly processing different stimuli. Some stimuli prove to be so insignificant that we barely pick up on them, while others are so vital that they consume our attention entirely. Our brains determine what stimuli to attend to, based on both the general salience of the stimulus and the specific relevance to our lives. Current emotional and physical states also play an important role in regulating attention. Indeed, emotions often consume our attention, sometimes even diverting our attention away from current goals. We focus on emotionally salient stimuli because they are physically or psychologically arousing (Pérez-Edgar & Fox, 2005). For example, in the moment of a bear attack, our emotions and fear cause us to focus entirely on the threatening stimuli in order to survive. Our ability to selectivity attend to certain stimuli as well as our biases to favor salient stimuli influence our everyday behaviors. While this is a general attention mechanism, evident across individuals, there are systematic differences in the stimuli that individuals find salient and the ease with which individuals engage with, or disengage from, salient stimuli.

The current study examines attentional processes in children ages 9-12 years when faced with neutral and threatening stimuli, incorporating both individual differences in temperament and electrophysiological markers of salience sensitivity. The process of favoring negative stimuli is known as attentional bias to threat (MacLeod, Matthews & Tata, 1986). Alternatively, an attentional bias towards a threat denotes the "differential attentional allocation towards a threatening and salient stimulus over a neutral stimulus" (Bar-Haim et al., 2007; MacLeod et al., 1986; Mogg & Bradley, 1998).

Attentional biases can be both beneficial and detrimental to our health. For example, in a life-threatening situation like a bear attack, it is crucial that we focus all of our attention on escaping the attack. However, it would be extremely damaging to our well-being to always focus our attention on the negative aspects--both objective and subjective--in our everyday environment. Previous research has proposed that hard-wired biases toward threat may interfere with individuals' attentional processes making it more difficult to disengage from negative stimuli, influencing socioemotional difficulties later in life (Pérez-Edgar, Taber-Thomas, Auday, Morales, 2014). This difficulty in disengaging from negative stimuli can shape how children navigate and perceive their environment (Todd et al., 2012). For example, during an emotional Stroop task, Pérez-Edgar and Fox (2003) found that a child's inability to ignore irrelevant negative emotion-related stimuli was linked to poor self-regulation.

Along with attentional biases, many other factors contribute to a child's ability to process and disengage from environmental stimuli. One factor known to play a pivotal role in attentional processes is temperament. Temperament can be characterized as a set of stable, "biologically-based individual differences in reactivity and regulation" (Rothbart and Derryberry, 1981). More specifically, the temperament trait of behavioral inhibition (BI) has been related to attentional bias to threatening stimuli. Behaviorally inhibited children experience more social rejection (Burgess et al. 2006; Whichmann et al. 2004), tend to avoid social stressors (Fox, Henderson et al. 2005; Pine 1999), and commonly respond to rejection with avoidance coping and blaming internal failings (Fox, Henderson et al. 2005). Many studies have found that behaviorally inhibited children have a more difficult time disengaging from negative stimuli than non-behaviorally inhibited children (Pérez-Edgar et al. 2014). Attention to threat has been further linked to social withdrawal. A link between behavioral inhibition in early life and social withdrawal in later life was found to be stronger in children demonstrating attention bias toward threatening stimuli (Pérez-Edgar et al. 2011). These findings introduce the question of whether there is a direct link between attention bias and social withdrawal.

A growing number of studies have examined the connections between attentional bias, behavior inhibition, and anxiety. A bias towards threatening stimuli may cause the individual to subjectively believe that his or her environment is threatening or distressing, causing a cycle of negative information processing that maintains anxiety (Pérez-Edgar et al. 2014). Anxiety is characterized by abnormal evaluation of, and reaction to social threats in addition to chronic impairment of functioning (Thai, Taber-Thomas, Pérez-Edgar, 2016). Children with BI typically show similar patterns of anxious behaviors, social withdrawal, and negative affect, which commonly resemble the characteristics used to diagnose anxiety disorders (Pérez-Edgar and Guyer, 2014). Attention biases to threat may act as one of the mechanisms linking early temperament to the later emergence of anxiety.

Despite the available data, additional research is needed in order to further understand how the mechanisms of attention bias in behaviorally inhibited children leads to social withdrawal and anxiety in adolescence. One way to take a closer look at these associations is to examine event-related potentials (ERPs) during an attention bias task. An ERP reflects brain activity due to a cognitive, sensory, or motor stimulus (Luck, 2005). ERPs detect changes in brain activity within an extremely short period of time. As such, they are extremely useful in studying early attentional processes linked to broader (e.g., behavioral) attention threat bias and the relationship with social anxiety.

Previous studies have utilized ERP data to track the neural patterns associated with attention processing in the presence of threatening and neutral facial stimuli by utilizing the dot-probe task. In one study the dot-probe task consisted of 80 experimental trials. Each trial began with a cross appearing in the center of computer screen, followed by a face pair (angry/neutral, happy/neutral, or neutral/neutral), which preceded an asterisk appearing on either the left or right side of the screen. The children were then asked to indicate as quickly as possible, which side of the screen the asterisk appeared. ERP data showing brain activity indicated a stronger significant positive correlation between behavioral inhibition and social withdrawal in children expressing attention bias than in children showing no attention bias (Pérez-Edgar et al., 2011). In a different experiment, a similarly designed dot-probe task was carried out while ERP data was analyzed for each of the face pairings. ERP data indicated enhanced C1 and P2 amplitudes in previously noted anxious individuals while no enhanced C1 and P2 amplitude was observed in non-anxious individuals. The ERP results suggest that an enhanced neural response may contribute to an attention bias to threat in anxious individuals (Eldar et al. 2010).

An alternative and additional task to the dot-probe task is an attention-cueing task designed by Michael Posner. The Posner task (Posner & Boies, 1971), relative to the dot-probe task, is better able to disentangle and track the engagement, disengagement, and reengagement of attention. Here participants are shown single cues in the periphery of the visual field, which better captures involuntary attention and forces individuals to disengage in order attend to subsequent target stimuli. In order to examine the impact of emotion on these attention processes, researchers have modified the task as an affective Posner task.

In the affective Posner task a cue, an affective facial stimulus, is presented in the left or right box on a computer screen. A target is then presented in either the same box (valid) or the opposite box (invalid). In an invalid trial, participants must disengage and shift their attention from the side of the screen the cue was on to the side of the screen that presents the target.

Researchers often use patterns of responses in the task to calculate the "validity effect", which is used to capture the difficulty a child has in disengaging from the target to the cue. This is measured by taking the reaction times of the invalid trials (face and cue in different positions) and subtracting the reaction times of the valid trials (face and cue in same position). An invalid trial will display an angry or neutral face followed by a square cue in the opposite location of the face. A valid trial will show an angry or neutral face, followed by a square box in the same exact spatial location as the face. The larger the score and the validity effect, the greater the influence attention shifting has on the child's performance. Therefore, it is predicted that behaviorally inhibited children will have larger validity scores due to their difficultly disengaging from threatening cues (Morales, Taber-Thomas, Pérez-Edgar, 2016).

One study in particular used the Posner task to analyze attentional bias patterns in children at temperamental risk for anxiety (Morales, Taber-Thomas, Pérez-Edgar, 2016). This study utilizes the dot-probe task in addition to the affective Posner task in order to compare patterns of attention bias during these two tasks in a population of children at risk for anxiety. The children were identified as behaviorally inhibited, or non- behaviorally inhibited, by parent-report. Results found no association between behavioral inhibition and performance in the dot-probe task. In contrast, results showed an increased attentional bias to threatening stimuli in behaviorally inhibited children during the affective Posner task. It was also concluded that children who consistently showed either high attention bias in both tasks or low attention bias in both tasks displayed higher levels of anxiety. The current study builds on the study conducted by

Morales, Taber-Thomas, and Pérez-Edgar (2016) by examining ERP-correlates of Posner task performance.

In addition to the validity effect, ERP's have also been used when conducting the affective Posner task. ERP data reflect temporary electric potential shifts in the EEG signal. These shifts, also known as ERP components, are thought to be caused by stimuli presented as well as psychological processes and reveal the different regions that support activity taking place in the brain. Different ERP components can help us further understand the attentional processes within the brain (Luck, 2005). Researchers study ERP components in hopes of better understanding the underlying processes supporting observed behavioral responses to environmental stimuli. The temporal sensitivity of the ERP wave can track psychological and biological processes that are often hidden, or averaged over, in behavior. By analyzing a variety of ERP components, researchers hope to ultimately draw conclusions pertaining to attention bias to threat and anxiety in behaviorally inhibited children.

Furthermore, a study (Pérez-Edgar and Fox, 2005) utilized the Posner task to compare ERPs between a group of shy and non-shy seven-year olds. The shy children showed larger ERP amplitudes and right electroencephalogram asymmetry throughout the Posner task. The results also demonstrated a bias toward the negative cues in the task, specifically among the shy children. Invalids cued stimuli delayed attention processing and may have resulted in slowed N2 amplitudes.

The P1 and N1 components capture early, automatic attentional processes (Thai et al. 2016). The P1 component is maximal in the occipital region and tends to indicate direction of spatial attention (Luck, 2004) and the subject's state of arousal (Vogel & Luck, 2000). The N1 component is particularly important in visual processes and reflects “perceptual facilitation of attended inputs, such as target enhancement and discrimination” (Thai et al. 2016)

In some studies, larger P1 components were found when a threatening stimulus (an angry face) was displayed relative to a neutral face (Pourtois et al., 2004; Santesso et al., 2008). This was especially evident in trials with anxious individuals (Li et al, 2005, 2007). Other studies did not show enhanced P1 results in subjects with social anxiety (Eldar et al., 2010). For example, a study of socially-anxious women found greater P1 and N1 amplitudes during the dot-probe task versus low socially-anxious individuals (Helfinstein et al., 2008).

Later components in the ERP wave, such as the P2 and N2, reflect higher-order cognitive processes in the brain. The P2 component has been recognized as being connected to elaborating attentional processing of emotional stimuli (Eldar et al. 2010, Carretié, Martin-Loeches, Hinojosa & Mercado, 2001). Eldar et al (2010) conducted a study using the dot-probe task with angry-neutral, happy-neutral, and neutral-neutral face pairs and found that anxious individuals showed greater P2 amplitudes to all face pairs in comparison to the control group.

The N2 component reflects control of attentional resources (Bar-Haim, 2010) and ‘conflict monitoring’ (Yeung and Cohen, 2006) pertaining to attempts of directing attention away from threat (Dennis and Chen, 2007, 2009). It also is thought to be involved in “top-down executive function, specifically to signal the need to inhibit a prepotent response to allow for the execution of subdominant behavior” (Thai et al., 2016). Hum et al. (2013) used a go/no-go task to find that clinically anxious college students had greater N2 activation than non-clinically anxious college students. Of particular interest to the current study, children high in BI show greater, more negative, N2 activation and a longer reaction times during a go/no-go task (Lamm et. al, 2014). The authors suggested that BI children display over controlled behavior and deploy excessive regulatory resources, linking increased N2 activation to greater anxiety.

The N170 component is also typically analyzed by researchers interested in face processing. For example, one study found that facial stimuli trigger a negative peak around 170ms that is larger relative to non-face stimuli (Bentin et al., 1996; Rossion et al., 1999).

The current study is part of a larger program of research examining the link between BI, attention to threat, and anxiety. One initial study (Thai et al., 2016) examined the ERP correlates of attention bias during the dot-probe task. Thai and colleagues noted that increased P2 amplitude was associated with decreased symptoms of social anxiety. P2 amplitude was also inversely related to the relation between BI and social anxiety. In addition, a smaller N2 amplitude indicated a bias toward threat while a larger N2 amplitude indicated threat avoidance. As for the P1 amplitude, behaviorally non-inhibited subjects demonstrated a larger P1 amplitude for angry congruent versus angry incongruent probes.

The current study extends the initial work done by Thai, Taber-Thomas and Pérez-Edgar by examining ERP components generated by the affective Posner task. This task is better suited to examine the role of disengagement in the BI to attention link, further refining the findings from Thai et al (2016).

Based on Thai et al (2016) and Morales et al (2016), we hypothesize that:

- BI subjects will have a larger validity score than non-BI subjects for angry faces.
- BI subjects have greater anxiety, particularly if there is a higher validity score.

- ERP correlates, particularly N1, N2, P2, and P3 will moderate the relation between BI and attention bias as well as BI and anxiety. Based on Thai et al (2016) we hypothesize that P2 amplitude will impact anxiety levels, while N2 moderates levels of attention bias.

Chapter 2

Methods

Participants

The sample consisted of 254 9–12 year olds ($Mean_{age}$= 9.87 years, SD= 0.96), collected from a large study on temperament, attention, and anxiety. Participants were recruited using the university's database of families interested in participating in research studies, community outreach, and word-of-mouth throughout Central Pennsylvania and neighboring areas. 702 participants were screened using parental report on the Behavioral Inhibition Questionnaire (BIQ; Bishop et al., 2003). Children who met BI cutoff scores (≥119 total score or ≥60 social novelty subscale) were identified and oversampled, such that although only 24.6% of the children met BI criteria, they represent 34.5% of the current study sample (88 behaviorally inhibited and 166 non-behaviorally inhibited). Cutoff scores were selected from a previous study of extreme temperament in children 4–15 years of age (Broeren and Muris, 2010). The sample was 2.1% Asian Pacific American, 48.7% Caucasian, 2.1% African American, 1.6% Hispanic, 2.6% biracial, and 42.9% declined to respond. All parents and children provided written consent/assent. Participants received monetary compensation for participating in the study.

Two participants were excluded for poor performance on the Posner task (< 75% accuracy). 81 participants were excluded due to significant artifacts (see EEG data reduction section for details), refusal to participate, and or completion of an earlier version of the task.

Thus, 171 participants represented our final sample, providing both behavioral and ERP data. For additional demographics see Table 1 in Results.

Measures

Behavioral inhibition was measured using the BIQ (Bishop et al., 2003), a 30-item measure assessing the frequency of BI-linked behavior in the realms of social and situational novelty on a 7-point scale from 1 (‘hardly ever’) to 7 (‘almost always’). The questionnaire has sufficient internal consistency and validity in separating BI from BN children (Bishop et al., 2003) and parent-reports on the BIQ correlate with laboratory observations of BI (Dyson, Klein, Olino, Dougherty & Durbin, 2011). The BIQ had good internal consistency in the current study ($\alpha = 0.86$).

Social anxiety symptoms were assessed through parent-report on the computerized Diagnostic Interview Schedule for Children version 4 (C-DISC 4; Shaffer, Fisher, Lucas, Dulcan & Schwab-Stone, 2000). A trained research assistant directed the semi-structured interview, where parents judged anxiety symptoms according to the DSM-IV as either present (‘yes’) or absent (‘no’). A count measure of endorsed symptoms was used in this study.

Posner Task

Participants were seated 40 cm from a 16-inch computer monitor. The monitor displayed a series of cues and targets on the screen. Each trial began with a 500 ms fixation, followed by a cue which consisted of an angry or neutral face from the NimStim stimulus set (Tottenham et al.,

2009) presented on either the middle, left, or right of the fixation (500 ms). The face is then followed by a target, a white square (1000 ms), in either the same spatial location as the cue, the opposite spatial location as the cue, or in the middle of the screen. Participants indicated as quickly and accurately as possible the location of the square by pressing a button (response recorded for 2500 ms). The visual angle for the face stimulus was 3.8º(H)*4.7º(V). The intertrial interval was 500 ms.

A target appearing in the same location as the facial cue was considered a valid trial, a target appearing on the opposite side of the facial cue was considered an invalid trial, and a target appearing in the middle of the screen was considered a middle trial. Furthermore, each trial was classified by the cue type: angry or neutral and the target location: valid, invalid, and middle. For example, an angry face followed by a white box in the opposite location of the cue is an angry invalid trial whereas a neutral face followed by a white box in the middle of the screen is a neutral middle trial. There was an average of 33 trials per condition: angry valid trials, angry invalid trials, angry middle trials, neutral valid trials, neutral invalid trials, and neutral middle trials. The middle trials served as controls and catch trials.

Calculation of validity effect for Posner task

A validity score was calculated by subtracting the reaction time (RT) to targets in valid trials from the RT to targets in the invalid trials. A separate validity score was calculated for angry cues and neutral cues. A larger validity score indicated greater difficulty disengaging from the cues and shifting attention towards the targets.

Electrophysiological recording and reduction

Electroencephalogram (EEG) activity was recording continuously throughout the performance of the Posner task using a 128-channel geodesic sensor net (Electrical Geodesics Inc., Eugene, Oregon). The EEF signal from each channel was digitized at a 1000 Hz sampling rate. EEG channels were gathered with reference to Cz and, after collected, re-referenced to the average of the left and right mastoids. Vertical eye movements were recorded from electrodes places approximately 1 cm above and below each eye. Horizontal eye movements were monitored with electrodes places approximately 1 cm at the outer canthi or each eye. Impedances were kept below 50 kΩ.

Brain Vision Analyzer (Brain Products GmbH, Germany) was used for all data preparation and processing after the recording. Data were filtered with a high-pass frequency of 0.1 Hz and a low-pass frequency of 40 Hz. The Gratton method (Gratton et al., 1983) was used to correct ocular artifacts from eye blinks and horizontal eye movements. Data time-locked to face displays were segmented into epochs from 100 ms before baseline to 500 ms after display onset, with 100ms baseline correction. EEG signals with artifacts greater than ±100 V were removed. Trials with incorrect response, no response, or latencies faster than 150 ms or exceeding 2000 ms were excluded from analyses. All included participants provided at least 30 artifact-free segments with at least 10 segments per condition. After inspecting the grand average ERP's, and in accordance with recent literature on the electrophysiological correlates of spatial attention (Eldar et al., 2010; Mueller et al., 2009; Rossignol et al., 2013), ERP analyses concentrated on the mean amplitudes of the N1, N2, P2, and P3 elicited by the facial cue. The N1 (60-180 ms), N2 (170-240 ms), P2 (180-280 ms), and P3 (220-400 ms) were quantified as the average mean amplitudes.

Model Testing

The initial analyses used repeated measures ANOVA to examine mean RT and mean amplitude relations for the Posner task. Each model used Trial Type (angry, neutral) as a within-subject factor and Group (BI, BN) as a between-subjects factor. Separate models were run for RTs for angry and neutral faces, and for the ERP amplitude for each component. In addition, we used zero-order correlations to examine the direct relations between BI, social anxiety, and the affective Posner task.

A moderated mediation model assessed the potential mediating or moderating role of attention disengagement on the relation between BI and social phobia through the use of SPSS (Version 22; Chicago, IL, USA) macro PROCESS model 74 (Hayes, 2012). BI was entered as the predictor, validity effect as the mediator, and social anxiety as the outcome. The model was used once using neutral validity effect as the mediator and once using angry validity effect as the mediator (Figure 1).

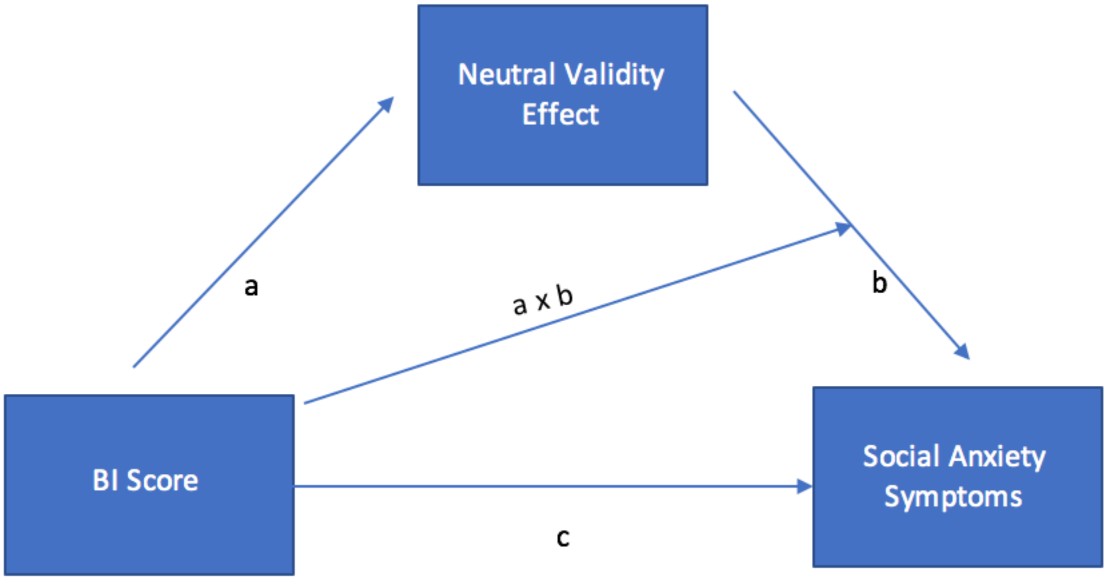

Figure 1: Process model 74 was used to examine potential moderated mediation of the BI-Anxiety link by attention to threat.

To assess the relations between BI, validity effect, ERP correlates of validity effect, and social anxiety, we tested a moderated mediation model (Hayes, 2015; Preacher et al., 2007) separately for each ERP component: N1, N2, P2, and P3 using SPSS (Version 22; Chicago, IL, USA) macro PROCESS model 59 (Hayes, 2012). BI was entered as the predictor, validity effect as mediator, and social anxiety as outcome, each ERP component serving in turn as the moderator (Figure 2). This model was tested once using validity effect for neutral faces and an additional time using validity effect for angry faces. Predictor, mediator, and moderator variables were mean centered prior to analysis. Significant conditional indirect effects were determined using 95% bootstrap bias corrected confidence intervals (CIs) based on 10,000 bootstrap samples.

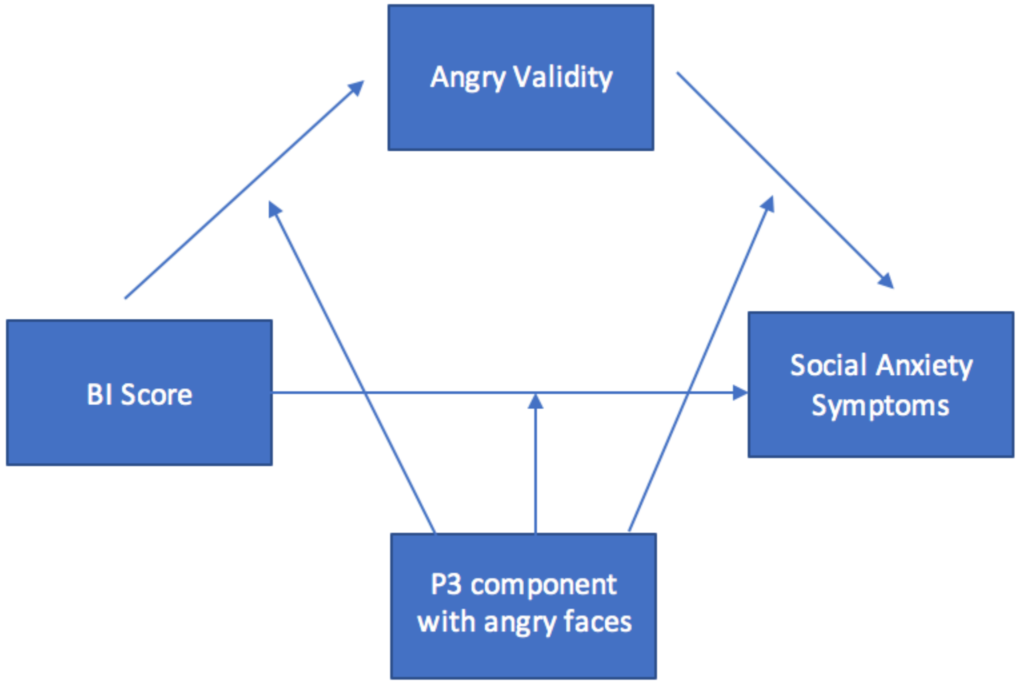

Figure 2: Process model 59 was used to test the relations between behavioral and psychophysiological markers of attention and the expected BI-Attention link.

Chapter 3

Results

Demographics

Table 1 presents the demographic and descriptive values for the core measures in the study. The BI and non-BI children differed only in BIQ score and Social Anxiety symptoms, as expected.

Table 1

	Behaviorally Inhibited		Behaviorally Non-Inhibited	
	Mean:	Std. Dev.:	Mean:	Std. Dev.:
BIQ	127.48	18.52	75.37	21.31
Age at visit	10.78	1.03	10.90	0.96
Mean N1 amplitude (angry)	-2.79	2.48	-3.37	2.67
Mean N2 amplitude (angry)	2.33	2.90	2.04	3.60
Mean P2 amplitude (angry)	0.90	3.57	1.13	4.10
Mean P3 amplitude (angry)	5.19	4.04	5.65	3.69
Mean N1 amplitude (neutral)	-2.71	2.63	-3.16	2.56
Mean N2 amplitude (neutral)	1.94	2.79	2.19	3.37
Mean P2 amplitude (neutral)	0.89	3.51	1.33	3.60
Mean P3 amplitude (neutral)	4.98	3.20	5.72	3.28
Social Anxiety	3.45	3.69	0.45	1.57
Sex (M/F)	38/50		77/89	

Behavioral Results

The 2 (Trial type) by 2 (BI Group) repeated measures ANOVA found neither a main effect for face emotion, $F(1,187) = 0.05$, $p=0.82$, nor an interaction between face emotion and BI-group, $F(1,187)= 0.12$, $p=0.73$. However, there was a marginal main effect of BI-group, $F(1,187)= 3.31$, $p=0.07$, reflecting the fact that BI children had a larger validity effect for both angry and neutral faces as hypothesized (16.18 vs. 7.57).

Table 2: Mean validity effect for the BI and non-BI groups

	BI	Non-BI	Main Effect of Face
Angry face	15.39	7.73	11.56
Neutral face	16.98	7.74	12.19
Main Effect of BI	16.18	7.57	

Mean ERP Amplitudes

As with the RT data, we completed a series of 2 X 2 ANOVAS, here using the mean amplitude for each ERP component as the dependent variable.

The N1 Component

The main effect for face emotion was not significant, $F(1,164) = 1.27$, $p=0.262$, nor was the interaction between face and BI-group, $F(1,164)= 0.377$, $p=0.54$. However, there was a trending main effect of BI-group, $F(1,164)= 2.04$, $p= 0.155$, reflecting the fact that BI children had a smaller mean N1 amplitude for both angry and neutral faces (BI: -2.75 vs. Non-BI: -3.30).

Table 3: Mean N1 amplitudes

	BI	Non-BI
Angry Face	-2.79 (0.32)	-3.43 (0.26)
Neutral Face	-2.71 (0.32)	-3.16 (0.26)

The N2 Component

We failed to find any significant effects, including the main effect for face emotion, $F(1,164) = 1.33$, $p=0.251$, the main effect of BI-group, $F(1,164)= 0.001$, $p= 0.97$, and the interaction between face and BI-group, $F(1,164)= 2.06$, $p=0.15$.

Table 4: Mean N2 amplitudes

	BI	Non-BI
Angry Face	2.41	2.14
Neutral Face	1.94	2.19

The P2 Component

We failed to find any significant effects, including the main effect for face emotion, $F(1,164) = 0.57$, $p=0.45$, the main effect of BI-group, $F(1,164)= 0.15$, $p=0.70$, and the interaction between face and BI-group, $F(1,164)= 1.23$, $p=0.27$.

Table 5: Mean P2 amplitudes

	BI	Non-BI
Angry Face	0.96	0.94
Neutral Face	0.89	1.33

The P3 Component

We failed to find any significant effects, including the main effect for face emotion, $F(1,164)= 1.16$, $p=0.28$, the main effect of BI-group, $F(1,164)= 1.47$, $p=0.23$, and the interaction between face and BI-group, $F(1,164)= 0.30$, $p=0.58$.

Table 6: Mean P3 amplitudes

	BI	Non-BI
Angry Face	0.96	0.94
Neutral Face	0.89	1.33

Correlations between ERP latency, BIQ and Social Anxiety

A bivariate correlation was used to examine the relations between mean amplitudes of the ERP components, BIQ score, and Social anxiety. As expected, BI score was positively correlated with social anxiety symptoms, $r(209)= 0.525$, $p < .001$.

There was a negative correlation between BIQ score and P3 mean amplitudes in the neutral condition, $r(166)= -0.148$, $p= .057$. Given a neutral facial cue, subjects with larger BIQ scores exhibited smaller P3 means amplitudes (Table 7).

There were also negative correlations between social anxiety and P3 mean amplitudes in both neutral and angry conditions respectively, $r(165)= -0.186$, $p= 0.017$, and, $r(170)= -0.168$, *p*=.028. Therefore, regardless of the facial cue, subjects with higher social anxiety displayed smaller P3 mean amplitudes (Table 8).

Table 7

	BIQ Score
Mean N1 amplitude- angry	0.081
Mean N1 amplitude- neutral	0.050
Mean N2 amplitude- angry	0.048
Mean N2 amplitude- neutral	-0.061
Mean P2 amplitude- angry	-0.059
Mean P2 amplitude- neutral	-0.110
Mean P3 amplitude- angry	-0.080
Mean P3 amplitude- neutral	-0.148^{+}

$^{+}p < .06$, $^{*}p < .05$

Table 8

	Social Anxiety
Mean N1 amplitude- angry	-0.060
Mean N1 amplitude- neutral	-0.049
Mean N2 amplitude- angry	0.005
Mean N2 amplitude- neutral	0.018
Mean P2 amplitude- angry	-0.076
Mean P2 amplitude- neutral	-0.102
Mean P3 amplitude- angry	-0.160*
Mean P3 amplitude- neutral	-0.186*

$^{+}p < .06$, $^{*}p < .05$

BI and Social Anxiety moderated by validity effect

PROCESS model 74 was first used to examine the potential mediating or moderating role of attention disengagement (using the RT validity effect) on the relation between BI and social anxiety, for angry trials. The only significant effect ($p < 0.001$) seen in Table 9 is higher levels of BI predict higher levels of social anxiety, as expected. Neither the validity effect nor the interaction between BI and Validity effect was significant in predicting social anxiety.

Table 9: Moderated mediation model examining the relation between the behavioral validity effect for angry faces, BI, and social anxiety.

BI Score – Angry Validity Effect (a)	Angry Validity Effect – Social Anxiety Symptoms (b)	BI Score – Social Anxiety (c)	BI Score x Angry Validity Effect – Social Anxiety (a x b)

B (SE)	t	B (SE)	t	B (SE)	t	B (SE)	t
0.10 (.09)	1.16	0.005 (.005)	0.10	.05 (.006)	8.49*	0.000 (.0002)	0.31
F(1, 184)= 1.35, *p*=0.25		*F*(3, 183)= 24.55, *p* < .001					

**p* < .05, ***p* <.01

Second, PROCESS model 74 was again used to examine the different interactions predicting validity effect and social anxiety during neutral trials as well. The results are shown in Table 10. A main effect (*t*=-2.51, *p*=.01) indicated that validity scores for neutral trials significantly predicted social anxiety. In addition and as expected, BI score predicts social anxiety (*t*=8.88, *p* <.001). Lastly a significant interaction between BI score and validity effect was noted, predicting social anxiety (*t*=-2.96, *p*= .004).

Table 10: Moderated mediation model examining the relation between the behavioral validity effect for neutral faces, BI, and social anxiety

BI Score – Neutral Validity Effect (a)		Neutral Validity Effect – Social Anxiety (b)		BI Score – Social Anxiety (c)		BI Score x Neutral Validity Effect – Social Anxiety (a x b)	
B (SE)	t	B (SE)	t	B (SE)	t	B (SE)	t
0.014 (0.08)	0.17	-0.013 (0.005)	-2.51*	0.05 (0.006)	8.88*	-0.001 (0.0002)	-2.96*
***F*(1,184)= 0.03, *p*=0.86**		*F*(3,182)= 31.86, *p* < .001					

**p* < .05, ***p* <.01

Through further examining the correlation between neutral validity score and social anxiety symptoms separately for the BI and non-BI groups, we found a significant correlation, *r*(80)= -0.303*, p*=0.006*,* between the validity effect (neutral) and social anxiety in BI subjects only (Table 11). The correlation approached significance for the BN subjects, *r*(106)= -0.186, *p*=0.056.

Table 11: Correlation effect between the neutral validity effect and social anxiety, separately for the BI and BN children.

		Social anxiety
Validity Effect (neutral)	BI	-0.303*
	BN	-0.186^{+}

*p <.05, **p <.10

Electrophysiological Results: Angry trials

As noted, we used Model 59 to examine moderated mediation models for the N1, N2, P2, and P3 components. BI was entered as the predictor, validity effect for angry faces as mediator, social anxiety as outcome, and ERP component for angry faces as moderator.

Path results for the N1, N2, and P2 moderated mediation models revealed a significant association only between BI and social anxiety (β*'s* >.04, p*'s* <.01). A marginal main effect was seen between N1 and social anxiety. No significant relation was found between validity effect and social anxiety for any of the ERP components.

A marginal effect showed the N1 amplitude negatively associated with social anxiety (β= -0.14, p= 0.08; Table 12). N2 moderated the conditional indirect effect of validity effect of social anxiety (β= 0.003, p=0.048, $0.000 \leq CI_{95\%} \geq 0.007$). Probing the interaction at +/- 1 standard deviation of mean N2, we found that at increasing levels of N2, the relation between validity effect and social anxiety strengthened. We found no significant relation between the validity effect and social anxiety in this model.

Table 12: Process model 59 angry trials results

	β (SE)	*t*	*β (SE)*	*t*
	Mediator: Validity Effect		Outcome: Social Anxiety	
N1	1.00 (1.17)	0.86	-0.14 (0.08)	-1.74^{+}
BI	0.11 (.09)	1.18	0.05 (0.01)	7.44**
N1 x BI	-0.03 (0.03)	-0.91	0.00 (0.00)	-0.85
VE			0.00 (0.01)	0.19
N1 x VE			0.00 (0.00)	0.23
N2	-0.78 (0.88)	-0.88	-0.00 (0.06)	-0.06
BI	0.13 (0.09)	1.45	0.05 (0.01)	7.46**
N2 x BI	-0.04 (0.03)	-1.28	0.00 (0.00)	-0.87
VE			0.00 (0.01)	0.48
N2 x VE			0.00 (0.00)	2.00*
P2	0.64 (0.77)	0.83	-0.05 (0.05)	-0.92
BI	0.12 (0.09)	1.29	0.04 (0.01)	7.26**
P2 x BI	-0.01 (0.02)	-0.67	0.00 (0.00)	-1.60
VE			0.00 (0.01)	0.09
P2 x VE			0.00 (0.00)	0.71
P3	0.29 (0.77)	0.37	-0.11 (0.05)	-2.19*
BI	0.12 (0.09)	1.30	0.04 (0.01)	7.41**
P3 x BI	-0.01 (0.02)	-0.33	0.00 (0.00)	-2.06*
VE			0.00 (0.01)	0.62
P3 x VE			0.00 (0.00)	2.54*

Note. BI= Behavioral Inhibition Score. VE= Validity Effect.
$^{+}$ *p < 0.10, * p < 0.05, **p < 0.01*

P3 amplitude was negatively associated with social anxiety (β= -0.11, p= 0.03; Table 12). Further, P3 moderated the conditional direct effect of BI on social anxiety ($-0.006 \leq CI_{95\%} \geq -0.001$). Probing the interaction at +/- 1 standard deviation of mean P3, we found that at decreasing levels of P3, the relation between BI and social anxiety strengthened (β= 0.00, p=0.04, $-0.006 \leq CI_{95\%} \geq -0.001$). In addition, P3 moderated the conditional indirect effect of validity effect of social anxiety (β= 0.004, p=0.01, $0.001 \leq CI_{95\%} \geq 0.007$). Probing the interaction at +/- 1 standard deviation of mean P3, we found that at increasing levels of P3, the relation between validity effect and social anxiety strengthened.

Electrophysiological Results: Neutral trials

Again, we used Model 59 to examine moderated mediation models for the N1, N2, P2, and P3 components. BI was entered as the predictor, validity effect for neutral faces as mediator, social anxiety as outcome, and ERP component given neutral faces as moderator.

Path results for all components, N1, N2, P2, and P3, revealed a significant association between BI and social anxiety (*β's* >.04*, p's* < 0.01). In addition, path results for the N1, N2, and P2 moderated mediation models revealed a significant association between validity effect and social anxiety (*β's* = -0.01*, p's* < 0.05). Additionally, a marginal effect was seen for the P3 component (*β*= *-1.65, p*= 0.102). In each case, a smaller validity effect was associated with greater social anxiety.

There was a validity effect by P3 interaction predicting social anxiety ($\beta = 0.005$, $p = 0.02$, $0.001 \leq CI_{95\%} \geq 0.008$). Probing the interaction at +/- 1 standard deviation of mean P3, we found that at increasing levels of P3, the negative relation between validity effect and social anxiety strengthened. There was a marginal interaction of P3 by BI in predicting social anxiety (β = -0.003, $p = 0.053$, $-0.007 \leq CI_{95\%} \geq 0.000$). Probing the interaction at +/- 1 standard deviation of mean P3, we found that at increasing levels of P3, the positive relation between BI and social anxiety weakened.

Table 13: Process model 59 neutral trials results

	β (SE)	*t*	*β (SE)*	*t*
	Mediator: Validity Effect		Outcome: Social Anxiety/ social anxiety	
N1	0.42 (1.14)	0.37	-0.09 (0.08)	-1.09
BI	-0.01 (0.09)	-0.11	0.05 (0.01)	7.38**
N1 x BI	-0.01 (0.04)	-0.39	0.00 (0.00)	0.11
VE			-0.01 (0.01)	-2.22*
N1 x VE			0.00 (0.00)	0.43
N2	-0.63 (0.89)	-0.71	0.04 (0.06)	0.58
BI	-0.01 (0.09)	-0.08	0.05 (0.01)	7.44**
N2 x BI	-0.05 (0.03)	-1.88+	0.00 (0.00)	-0.47
VE			-0.01 (0.01)	-2.15*
N2 x VE			0.00 (0.00)	1.12
P2	0.30 (0.84)	0.36	-0.05 (0.06)	-0.88
BI	-0.01 (0.09)	-0.09	0.05 (0.01)	7.21**
P2 x BI	-0.03 (0.02)	-1.25	0.00 (0.00)	-0.81
VE			-0.01 (0.01)	-2.23*
P2 x VE			0.00 (0.00)	0.66
P3	0.90 (0.86)	1.04	-0.08 (0.06)	-1.32
BI	-0.01 (0.09)	-0.09	0.04 (0.01)	7.25**
P3 x BI	-0.04 (0.02)	-1.42	-0.003 (0.00)	-1.95+
VE			-0.01 (0.01)	-1.65
P3 x VE			0.00 (0.00)	2.43*

Note. BI= Behavioral Inhibition Score. VE= Validity Effect.
$^{+}p < 0.10$, $*p < 0.05$, $**p < 0.01$

Chapter 4

Discussion

The current study examined the electrophysiological markers associated with the validity effect and behavioral inhibition, both markers known to influence social anxiety through performance on the Posner task. This study is part of a larger study examining the relation between BI, attention bias, and anxiety. We specifically chose to use the Posner task in hopes of gaining a stronger understanding of the role of disengagement in BI children.

First, a marginal main effect was seen among BI group and the validity effect, reflecting that BI children exhibit larger mean validity scores than non-BI children regardless of the facial stimuli presented. A greater validity effect, or attention bias, implies a slower response when a shift in attention is required. Therefore, the data indicate that children with behavioral inhibition have greater difficulty redirecting their attention. These results are consistent with prior research that suggests behavioral inhibition is accompanied by disturbance in attention control (Fox, Hane, & Pine, 2007; Fox, Henderson, Pérez-Edgar, & White, 2008). A greater validity effect in the BI subjects, and therefore a longer disengagement period appears because greater behavioral inhibition is affiliated with a sequence of elevated vigilance and behavioral monitoring (White et al., 2015); which in turn accounts for the difficulty in disengaging for the BI subjects.

These results are inconsistent with our first hypothesis that states BI subjects will have larger validity scores in only angry trials. The lack of a significant distinction with face affect implies that the BI subjects have greater difficulty redirecting their attention overall, compared to the non-BI subjects. Hum and colleagues (2013) found that clinically anxious children displayed continuous increased neural activation, "as though they were engaged in processes of emotion regulation, regardless of the stimulus [emotion]" (p. 558). Hum anticipated this was due to the fact that all of the stimuli were deemed threatening or because the children felt anxious throughout the entire experiment and therefore were less responsive to the differences in the information presented. It is possible that BI children may differentially process neutral faces as ambiguous and also avoiding the neutral face, thus leading to larger validity effect scores in both angry and neutral trials.

As expected, across all models we saw higher levels of BI predicting high levels of social anxiety. The exact factors that influence this relation are yet to be fully understood and one of the many relations this study seeks to answer. One recent study proposes that behavioral inhibited children are excessively worried about their performance and making mistakes, particularly in a social setting. A child who exhibits these types of concerns as well as high in inhibitory control, may not successfully control their attention processes which likely results in over-controlled behaviors. The over-controlled behaviors then result in anxious behaviors (Derryberry & Rothbart, 1997; Rothbart & Sheese, 2007). Another study (White et al., 2011) found that BI children with high levels of attention shifting were at less risk of developing anxiety than BI children with difficulty in attention shifting. In contrast, the same study found that high levels of inhibitory control may increase the risk of anxiety in behaviorally inhibited children (White, 2015). Given these predictions, it is evident that multiple attention mechanisms may both buffer and bolster the relation between levels of behavioral inhibition and greater social anxiety symptoms.

When analyzing the moderating role of validity effect (invalid- valid trials) on the relation between BI and social anxiety, we found no significant moderation relations during the angry trials. However, during neutral trials, a significant effect was seen with the interaction of BI score and validity effect in predicting social anxiety. A closer investigation revealed a negative correlation between the neutral validity effect and social anxiety that was only significant among BI participants. These findings contradict our second hypothesis that larger validity scores would potentiate the relation between BI and anxiety.

Further findings relating to validity score revealed that during neutral trials, the BI participants' response to ambiguity has a unique impact on (*or* is associated with) anxiety while their response to threatening stimuli is not differentially associated with anxiety. "BI children experience more social rejection, interpret ambiguous social encounters as particularly rejecting…[and] more vigorously tend to avoid social stressors" (Fox and Pine, 2012, p. 125). Consequently, the smaller validity effect during the neutral trials may be a result of the BI children readily avoiding the neutral cues. The BI children also tend to display exaggerated sensitivity to novelty (Kagan, Reznick, & Snidman, 1988) and thus avoidance coupled with heightened sensitivity, may exacerbates anxiety.

Overall, we found little support for the influence of ERP-correlates of attention on the relation between BI and anxiety. We did note a marginal main effect of BI-group with the N1 component, indicating that BI children exhibited smaller mean N1 amplitudes in both angry and neutral trials. In addition, a smaller N1 amplitude was significantly related to increased social anxiety. The N1 component has been known to represent early, automatic visuospatial orienting of attention (Hillyard & Anllo-Vento, 1998; Luck et al., 1990). Additionally, Luck (1994) found that the N1 amplitude is largest when attention is focused solely on areas of the visual field where pertinent information is presented in contrast to when attention in distributed evenly across the visual field or specifically focused on an area of irrelevant information. As explained by larger validity effect, a behaviorally inhibited child may have trouble shifting and controlling their attention to focus their attention on the important stimuli in the visual field and therefore display smaller N1 amplitudes than non-behaviorally inhibited children who can more easily orient their attention. Toddlers with high levels of behavior inhibition predicted high levels of social anxiety throughout preschool years only when the child presented low levels of attention shifting (White et al., 2011). Therefore, children with smaller N1 amplitudes may be more likely to experience greater social anxiety.

Although we hypothesized the N1, N2, P2, and P3 ERP correlates would moderate the relation between BI and attention bias as well as BI and social anxiety, only the N2 and P3 components played a significant role in the relation between BI, attention bias and social anxiety. Our hypothesis specifically predicting that the P2 amplitude would impact anxiety levels was not supported as no significant results were found relevant to the P2 component.

When examining the separate correlations between mean amplitudes of the P3, social anxiety, and BIQ score, a marginal negative correlation was seen between P3 mean amplitudes and BIQ score within the neutral trials only. This relation suggests that children with higher BIQ scores exhibited smaller P3 amplitudes during the neutral trials. No effect between BIQ score and P3 amplitude was seen during the angry trials. In addition, a larger P3 amplitude was associated with a significant relation between validity effects and social anxiety. The P3 amplitude is largely known to be indicative of certainty, more specifically the amplitude is smaller when subjects are uncertain if the stimulus is indeed a target (Luck, 2014). A BI child's ambiguous response to the neutral stimuli plays a crucial role in the child's confidence in interpreting the given facial expression. Therefore a child with a high BI score may have higher levels of doubt and uncertainty, resulting in a smaller P3 components. Additionally, a smaller P3 mean amplitude was correlated with increased levels of social anxiety across both trial conditions. Furthermore, P3 moderated the positive relation between BI and social anxiety, such that the relation between BI and social anxiety symptoms increased with decreases in P3. Relating back to the findings of Derryberry & Rothbart (1997) and Rothbart & Sheese (2007), BI children tend to be overly concerned about their performance and making mistakes, leading to over-controlled behaviors and ultimately display anxious behaviors. Thus, a smaller P3, as explained by greater uncertainty present in the Posner task, may exacerbate a BI child's concerns, thus leading to over-controlled behavior, and anxiety. Consequently, heightened uncertainty in children with larger BI scores leads to higher levels of social anxiety and smaller P3 amplitudes.

The data supported our hypothesis that the N2 component would moderate levels of attention bias. Much like the P3 component, the N2 component also moderated the relation between the validity effect and social anxiety during angry trials, such that the relation between validity effect and social anxiety symptoms strengthened with increases in N2. Past studies have found the N2 component to be linked to attention control (Van Veen and Carter, 2002) and efforts to redirect attention away from threatening stimuli (Dennis and Chen, 2007). Consequently, Eldar and Bar-Haim (2010) found subjects exhibited smaller N2 amplitudes following attention training away from threatening faces. In theory, a child lacking attention control has a harder time disengaging from the angry face in the Posner trial, demonstrated by larger validity effect scores. Their inability to direct attention away from the threatening faces is exhibited in larger N2 components and a stronger association between validity effect and social anxiety.

The findings from the study should be assessed in light of limitations. A core limitation to this study was sample size. Although the sample started out large, more than 30% of the sample was lost due to task- and participant-related reasons. A greater sample size will help create stronger and clearer ERP data and thus produce more stable results. Another limitation was that the ERP components were measured in terms of amplitude size only. Other studies have found important meaning in the latency of the ERP waves. Future studies should further examine the differences of onset time of the ERP components with the Posner task. Moreover, the role of BI and attention bias on social anxiety should be longitudinally studied across pre-teen and adulthood in order to better understand the development of social anxiety.

In the end, our study is one of the first studies to directly analyze electrophysiological markers pertaining to attention processes during the Posner task in healthy and behaviorally inhibited children. We found strong evidence pertaining to the link between attention bias in children with behavioral inhibition. We failed to distinguish any significant relationships relating to the P2 amplitude. Further examination brought to light possible underlying attentional processes related to the N1, N2, and P3 amplitudes. Specifically, the importance of the N1 in orientation of attention, the N2 component and its association to attention control, and the P3 components' role in prediction and certainty. Through the findings of this study, the data can help us begin to understand the complex factors pivotal in the development of social anxiety in children.

Appendix A

Behavioural Inhibition Questionnaire (Parent Form)

The following statements describe children's behaviour in different situations. Each statement asks you to judge whether that behaviour occurs for your child "*hardly ever*", "*infrequently*", "*once in a while*", "*sometimes*", "*often*", "*very often*", or "*almost always*". Please circle the number "1" if the behaviour "*hardly ever*" occurs, the number "2" if it occurs "*infrequently*", etc. Try to make this judgement to the best of your ability, based on how you think your child compares with other children about the same age.

1 Hardly Ever	**2** Infrequen-tly	**3** Once in a While	**4** Someti-mes	**5** Often	**6** Very Often	**7** Almost Always

1. Approaches new situations or activities very hesitantly	1	2	3	4	5	6	7
2. Will happily approach a group of unfamiliar children to join in their play	1	2	3	4	5	6	7
3. Is very quiet around new (adult) guests to our home	1	2	3	4	5	6	7
4. Is cautious in activities that involve physical challenge (e.g., climbing, jumping from heights)	1	2	3	4	5	6	7
5. Settles in quickly when we visit the homes of people we don't know well	1	2	3	4	5	6	7
6. Enjoys being the centre of attention	1	2	3	4	5	6	7
7. Is comfortable asking other children to play	1	2	3	4	5	6	7
8. Is shy when first meeting new children	1	2	3	4	5	6	7
9. Happily separates from parent(s) when left in new situations for the first time.	1	2	3	4	5	6	7
10. Is happy to perform in front of others (e.g., singing, dancing)	1	2	3	4	5	6	7

11. Quickly adjusts to new situations.	1	2	3	4	5	6	7
12. Is reluctant to approach a group of unfamiliar children to ask to join in	1	2	3	4	5	6	7
13. Is confident in activities that involve physical challenge (e.g., climbing, jumping from heights)	1	2	3	4	5	6	7
14. Is independent	1	2	3	4	5	6	7
15. Seems comfortable in new situations	1	2	3	4	5	6	7
16. Is very talkative to adult strangers	1	2	3	4	5	6	7
17. Is hesitant to explore new play equipment	1	2	3	4	5	6	7
18. Gets upset at being left in new situations for the first time.	1	2	3	4	5	6	7
19. Is very friendly with children he or she has just met	1	2	3	4	5	6	7
20. Tends to watch other children, rather than join in their games	1	2	3	4	5	6	7
21. Dislikes being the centre of attention	1	2	3	4	5	6	7
22. Is clingy when we visit the homes of people we don't know well	1	2	3	4	5	6	7
23. Happily approaches new situations or activities	1	2	3	4	5	6	7
24. Is outgoing	1	2	3	4	5	6	7
25. Seems nervous or uncomfortable in new situations	1	2	3	4	5	6	7
26. Happily chats to new (adult) visitors to our home	1	2	3	4	5	6	7
27. Takes many days to adjust to new situations.	1	2	3	4	5	6	7
28. Is reluctant to perform in front of others (e.g., singing, dancing)	1	2	3	4	5	6	7
29. Happily explores new play equipment	1	2	3	4	5	6	7
30. Is very quiet with adult strangers	1	2	3	4	5	6	7

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ACADEMIC VITA

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Education

B.S., Biobehavioral Health 2017
Schreyer Honors College, The Pennsylvania State University, State College, PA

International Education: University of Sydney, Sydney, Australia – Spring 2016

Thesis

Title: The Role of Attention Bias and Behavioral Inhibition in Predicting Children's Social Anxiety.
Thesis Supervisor: Koraly Pérez-Edgar

Honors and Awards

- Dean's List (Spring 2014- Spring 2017)
- College of Health and Human Development Honors Society (Spring 2014- Spring 2017)
- Recipient of Provost's Award (Fall 2013-Spring 2015)

Work Experience

- Thomas Jefferson University- Otolaryngology (Summer 2014, Summer 2016)
  Medical Shadow, Intern
  - Observed Facial Plastic/Reconstructive surgeons on pre and postoperative appointments
  - Videographer during reconstructive surgery in order to further teach residents
  - Re-branded medical forms used to inform patients about their upcoming surgeries
  - Created marketing pieces used to advertise various aesthetic procedures
  - Organized and facilitated the launch of the electronic Patient Portal

- Hospital of the Univ. of Pennsylvania- Cardiovascular Medicine (Summer 2015)
  Intern
  - Assisted with the groundwork for The Mobile CPR Project- Philadelphia; this project was designed to teach community members basic CPR training free of cost in order to decrease the amount of deaths due myocardial infarction per year
  - Located community centers, religious institutions and community events interested in hosting CPR training clinics
  - Served as a liaison between physicians and the previous project coordinator from The Mobile CPR Project- Rhode Island to establish possible beneficial changes

Research Experience

- Cognitive, Affect and Temperament Lab (Fall 2015-Summer 2017)
  - Coded vocal cues, temperamental cues, and body language of 9 to 12-year-old children
  - Participated in various tasks collecting data during the subjects' visits to be analyzed at a later time
  - Thesis: Studied the link between brain EEG activity, attention bias and social anxiety and behaviorally inhibited children.
- Behavioral Neurogenetics Lab (Fall 2014)
  - Coded motor movements in mice from prerecording videos
  - Observed the injection of the bPiDI drug into the mice
  - Assisted in analyzing the effects the bPiDI treatment had on the locomotor skills in mice