Shyness and Internalizing Problems in Middle Childhood: The Moderating Role of Attentional Control, Inhibitory Control, and Frontal EEG Asymmetry.

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(Abstract)

Shyness is highly related to internalizing problems. However, not all shy children develop serious internalizing problems (IP). The aim of the current study was to identify the endogenous factors that might contribute to the resilience process from a self-regulation perspective. Participants included 73 children (33 boys; 40girls) who visited the lab at 6 and 9 years of age. Shyness, attentional control (AC), inhibitory control (IC), frontal electroencephalogram (EEG) asymmetry were measured at both 6 and 9 years using age appropriate questionnaires and tasks. Results indicated that age 6 shyness did not directly predict age 9 IP; instead it indirectly predicted IP through age 9 shyness. Neither AC, IC, frontal EEG asymmetry, nor the stability of frontal EEG asymmetry moderated the association between age 6 shyness and age 9 IP. However, there was a positive concurrent association between shyness and IP at 9 years. In addition, AC and IC moderated the shyness-IP association at age 9. Shyness was significantly associated with IP only when children had low AC or IC, but not when children had high AC or IC.

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(General Audience Abstract)

Shyness is highly related to internalizing problems. However, not all shy children develop serious internalizing problems (IP). The aim of the current study was to identify the within-individual factors that might protect children away from having IP from a self-regulation perspective. Participants included 73 children (33 boys; 40girls) who visited the lab at 6 and 9 years of age. Shyness, attentional control (AC), inhibitory control (IC), frontal electroencephalogram (EEG) asymmetry were measured at both 6 and 9 years using age appropriate questionnaires and tasks. Results indicated that children who are shy at 6 years old may not have IP at 9 years old. Instead children who are shy at 6 years old tend to be shy at 9 years old. And those who are shy at 9 years old are more likely to have IP at the same period of time. Neither AC, IC, frontal EEG asymmetry, nor the stability of frontal EEG asymmetry affect the direction or degree of the association between age 6 shyness and age 9 IP. In addition, AC and IC affect the concurrent shyness-IP association at age 9. Shyness was significantly associated with IP only when children had low AC or IC, but not when children had high AC or IC.

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Introduction

Shyness is often conceptualized as wariness/anxiety in the face of social novelty and perceived social evaluation (A.H. Buss, 1985). Shy children and adults typically show discomfort and wariness in the presence of unfamiliar people (Briggs & Smith, 1986). According to A.H. Buss (1986), there are two kinds of shyness: fearful shyness and self-conscious shyness. Fearful shyness refers to fear and wariness when faced with social novelty. Self-conscious shyness refers to discomfort, caution, and inhibition of behavior when the person is being monitored or evaluated by others. A.H. Buss (1985) argued that self-conscious shyness develops only when children have a high level of cognitive “self-concept”; in other words, only when they have an advanced self-concepts as social objects. Thus, self-conscious shyness is a late-emerging shyness that develops after children are about five years old.

Shyness is one of the most stable temperament characteristics and has been reported to be concurrently and predicatively related to a wide range of internalizing problems (Rothbart &Mauro, 1990) including anxiety (Van Ameringen, Mancini, & Oakman, 1998), depression (Karevold, Ystrom, Coplan, Sanson, & Mathiesen, 2012), low self-perception (Nelson et al., 2008), and loneliness (Chen, Yang, & Wang, 2013). Work by K.A. Buss, however, suggests that not all children who present with shyness are at risk for developing anxiety (e.g., K.A. Buss, 2011; K.A. Buss & McDoniel, 2016; Rubin, 1993). Thus, it is important to understand different factors that influence the paths toward or away from risk (K.A. Buss & McDoniel, 2016; Morales, Perez-Edgar, & K.A. Buss, 2015). Previous research shows that environmental factors including attachment relationships (Rubin et al., 2009) and maternal personality (Coplan, Arbeau, & Armer, 2008) moderate the relation between shyness and socioemotional development. However, less is known about the endogenous factors that may affect the risk for developing internalizing problems among shy children. Research suggests that cognitive control (White, McDermott, Degnan, Henderson, & Fox, 2011) and frontal EEG asymmetry (Henderson, Fox, &Rubin, 2001) moderate the relation between negative reactivity (which includes shyness) and anxiety during infancy and toddlerhood. The goal of my thesis research project was to examine whether cognitive control and frontal EEG asymmetry moderate the association between shyness and internalizing problems during middle childhood.

1. Shyness and Internalizing Problems

Research suggests that shy children are at high risk for developing internalizing problems within and across time (Rothbart &Mauro, 1990). For example, Eggum and colleagues (2012) found that shyness was significantly related to internalizing problems over and above emotionality. Brumariu and Kern (2013) reported that shyness from 15 to 54 months was predictive of social anxiety at 5th to 6th grade. Moreover, shyness was reported to be positively related to internalizing problems in Italian preschool children (Sette, Baumgartner, & Schneider, 2014). Shyness was found to be positively and uniquely predicted later loneliness, depression, and teacher-rated internalizing problems in Chinese school-age children (Chen et al., 2013). These findings suggest that shyness is a risk factor for developing internalizing difficulties across cultures concurrently and longitudinally.

The high correlation between shyness and internalizing problems may relate to other negative developmental outcomes caused by shyness. For instance, shy or socially withdrawn children are more likely to be victimized and rejected by peers compared with non-shy children. As a result, they feel lonelier and have more negative peer relationships that cause their depressive mood (Boivin, Hymel, & Bukowski, 1995). Dill and colleagues (2004) found that shy children experience more victimization by peers, which gives rise to greater negative affect later. In addition, compared with non-withdrawn children, withdrawn children have less friends and poorer friendship quality (Rubin, Wojslawowojcz, Rose-Krasnor, Booth-LaForce, & Burgess, 2006; Pedersen, Vitaro, & Borge, 2007). Fordham and Stevenson-Hinde (1999) reported that shy children tend to have low global self-worth, and thus have more negative perceptions about social acceptance, peer-support, and more anxiety traits. The negative perceptions about self and others as well as the poor peer relationships caused by shyness undoubtedly exacerbate children's internalizing problems.

The above mentioned findings can partly explain why shyness is increasing related to internalizing problems with age (Gazelle & Rudolph, 2004). When children grow up, peer interaction and peer relationships account for a larger proportion of daily experiences and play a more significant role than when children are younger. So being shy or socially withdrawn puts children at a disadvantage for social development. Moran and colleagues (2013) found that fearful temperament at 36-40 months old did not predict internalizing problems 9 months later. They suggest it may because the problem caused by fearful temperament at this early age is mild and may later develop into more serious socioemotional problems during school age years. Rubin and colleagues (2006) indicate that shy children become increasingly rejected by their peers during early to middle childhood; since being shy is regarded as more abnormal and deviant behavior during this period of development. In view of this, it is particularly important to study how shyness as an important dimension of fearful temperament is predictive of internalizing problems during middle childhood. It is during middle childhood when children begin to interact with larger groups of unfamiliar people and when self-conscious shyness starts to develop.

2. Shyness, Effortful Control, and Internalizing Problems

Children who are characterized as shy or socially withdrawn tend to rigidly inhibit their behaviors and experience intense negative emotional reactivity including wariness, discomfort, and distress to unfamiliar social environment and people (Rothbart & Mauro, 1990). However, the situation will be different if children can actively and efficiently regulate these negative behavioral and emotional responses. Successfully regulating the negative responses helps children participate in social interactions and activities in a more positive and rewarding way, thus reducing the internalizing problems caused by shyness.

Effortful control (EC) is the ability to inhibit a dominant, salient response in order to perform a sub-dominant, less salient response via attentional control (focusing, shifting) and inhibitory control (Rothbart & Bates, 2006). Although EC is usually considered as a temperament-based construct, the development of it is highly related to cognition, especially the maturation of attentional system linked to the anterior attention network (Rothbart, Derryberry, & Posner, 1994). The successful exertion of EC also heavily relies on the individual’s attentional control and inhibitory control, which are important cognitive abilities. There are advocacies recently for developing an integrated framework of self-regulation that combines temperament-based control and cognitive control to improve the understanding of the role of self-regulation in academic and socioemotional development (Zhou, Chen, & Main, 2012; Liew, 2012).

Research has found that EC is an important protector against undesirable socioemotional outcomes (Dennis, Brotman, Huang, & Gouley, 2007; Eisenberg et al., 2001). For instance, Oldehinkel and colleagues (2007) report that EC attenuates the negative effect of fearfulness on internalizing problems. Given this, studying the EC skills applied in the regulation of negative responses is not only important from a theoretical perspective but also has significant clinical implications.

Although a large amount of research supports the protective role of EC in developing internalizing problems, some research fails to find this or even finds the opposite result (Murray & Kochanska, 2002; Thorell, Bohlin, & Rydell, 2004). A possible explanation is research studies use different aspects of EC. Some operationally defined EC at the attention level (attentional control) whereas others focused on inhibitory control, which is EC at the response or behavioral level. Given this, studying different aspects of EC in the relation between various aspects of negative affectivity, including shyness and internalizing problems, is necessary (Eisenberg et al., 2009).

In addition, the methods that are used to measure EC vary with each study. Some researchers used behavioral executive function tasks that may reflect children's control abilities under an unfamiliar and stressful condition, whereas others relied on parental report that may reflect children's control abilities across a broad range of situations (White et al., 2011). In my thesis study, I used both behavioral tasks and maternal reports to compute composite scores of subcomponents of EC (attentional control, inhibitory control) in order to have the most reliable and comprehensive indices of EC.

Moreover, the adaptive or maladaptive role of EC may vary as a function of temperament disposition (Degnan & Fox, 2007). For instance, although EC is a protector for most children, it actually exacerbates the negative effect of behavioral inhibition on social reticence (Henderson & Martin, 2004). More specifically, the roles of attentional control and inhibitory control may vary as a function of children's temperament disposition. For example, in a recent study, White and colleagues (2011) reported that for behaviorally inhibited children, attentional control reduces the possibility for having anxiety whereas inhibitory control increases this risk. Thus it is critical to include both temperament reactivity and different aspects of EC to examine the interactive effect of temperament affectivity and EC in predicting internalizing problems. Although shyness is different from behavioral inhibition in that it does not include a nonsocial component, they share lots of similarities including reticence, withdrawal, and inhibition of speech and behaviors in face of novelty (Rothbart & Mauro, 1990). Thus inhibitory control may not be a protector for shy children. It is important to differentiate between attentional control and inhibitory control when studying their roles in the relation between shyness and internalizing problems.

2.1 Moderating Role of Attentional Control

Attention control is a higher-order, goal-driven, and voluntary regulatory skill at the perceptual level. People with good attentional control ability are better able to selectively focus on target stimuli while inhibiting others, as well as shifting their attention when needed based on the goals or task demands (Diamond, 2013). With age and the maturation of the neural network which includes the anterior cingulate cortex (ACC) and dorsolateral prefrontal cortex (dlPFC; Milham, Bainch, Claus, & Cohen, 2003), attentional control becomes more efficient across early and middle childhood (Eisenberg et al., 2003). Rueda and colleagues (2004) reported that children's conflict scores in the ANT (Attention Network Task), a measure of attentional control, strongly developed from 6 to 7 years old. The same results were replicated in another research study that showed children's attentional control increased from age 6 to 7, and became stable after age 9 (Simonds, Kieras, Rueda, & Rothbart, 2007). In addition, Anderson and colleagues (2001) compared the developmental trajectory of attentional control between middle childhood (7- years old) and late childhood to early adolescence (11-15 years old). They found children's attentional control developed rapidly during middle childhood and was relatively stable in later childhood to adolescence. The rapid development of attentional control during middle childhood potentially allows children to exert greater control over their negative temperament disposition. Given this, we might expect that attentional control begins to lay a more critical role in children's adaptive development in middle childhood than ever before.

Furthermore, research suggests that attentional control serves as a protector that attenuates the relation between shyness and internalizing problems (Degnan & Fox, 2007). Eisenberg and colleagues (1998) found that shy children with poor attentional control had greater internalizing symptoms. The mechanism of how attentional control modulates the relation between shyness and internalizing problems may relate to the attentional biases toward threatening stimuli that are exhibited by shy children. LoBue and Pérez-Edgar (2014) reported that children with high shyness from age 4 to 7 demonstrated a greater bias for social threats than children with non-shyness. Individuals who were in low-shy group processed happy faces faster than other emotions and showed increased P1 amplitudes (an event-related potential, ERP, measured using EEG) for happy faces compared to neutral faces (Jetha, Zheng, Schmidt, & Segalowitz, 2012). Thus, both the behavioral and electrophysiological responses of the shy children differed from that of the non-shy children during the attention task.

Moreover, research suggests that attentional bias to threat shapes the relation between shyness and later undesired outcomes (Pérez-Edgar et a, 2011). Henderson (2010) reported that shy children showed poor outcomes only when they have greater response to conflict stimuli, which was indicated by enhanced N2 ERP amplitude. Hardee and colleagues (2013) used fMRI to study bias attention to threat and reported that behaviorally inhibited children had greater threat and attention-related fronto-amygdala connectivity. This negative connectivity moderated the correlation between childhood behavioral inhibition and adult internalizing problems. However, if shy children have good attentional control skills that reduce the negative attentional bias, allowing them to flexibly shift attention from threatening and distressing stimuli, then shy children may be at a lower risk for developing internalizing problems. Evidence from Lonigan and Vasey's (2009) research showed that negative affectivity was related to attentional bias only when children had less EC. Given the findings in the research literature, we have good reasons to believe that attentional control reduces the threat bias of shy children, and thus decreasing the risk for developing internalizing problems.

2.2 Moderating Role of Inhibitory Control

Inhibitory control is an important component of executive functions, which refers to the ability to intentionally inhibit or override a dominant response and to perform a subdominant one (Miyake et al., 2000). Research suggests that the efficiency of children's inhibitory control increases with age and the development of the prefrontal cortex (Williams, Ponesse, Schachar, Logan, & Tannock, 1999; Diamond, 2002; Durston et al., 2002), and shows robust stability longitudinally (Kochanska, Murray, & Coy, 1997). Diamond and Tayor (1996) reported that children's inhibitory control increased from $3^{1}/_{2}$ and 7 years old, with most of the improvement happening before age 6. This result was also reported by Schachar and Logan (1990), who found that inhibitory control ability developed little after Grade 2, which would be about age 7. Thus children's inhibitory control ability improves across early childhood and seems to reach a relatively high and stable level in middle childhood. So middle childhood is the first period of time when inhibitory control exerts the most influence on children's development.

Most research that studies inhibitory control focuses more on its relation with externalizing problems. Children with less inhibitory control are more likely to develop externalizing problems (Olson, Sameroff, Kerr, Lopez, & Wellman, 2005; Utendale & Hastings, 2011; Valiente et al., 2003). The role of inhibitory control in internalizing problems has been less examined and the few findings regarding this are inconsistent. Thorell and colleagues (2004) studied two types of inhibitory control and their relations to social development. One is inhibition to unfamiliar, which is a temperament-based unintended effortful control and is very similar to behavioral inhibition. The other is inhibitory control, which is a cognitive intended control process we are interested in here. They found that the two types of inhibitory control were respectively related to low levels of hyperactivity. However, the combination of both types of inhibition was related so high social anxiety. Based on this finding, the role of inhibitory control may differ for children with high level of behavioral inhibition. Indeed previous research has found evidence to support this hypothesis. For example, behaviorally inhibited children at 2 years of age who also had high levels of inhibitory control at age 4 were at greater risk for preschool anxiety (Osher, Martin McDermott, Degnan, Dubin, & Fox, 2007). McDermott and colleagues (2009) found that high levels of early childhood behavioral inhibition and adolescence response monitoring were related to later-life clinical anxiety. The reason for that may because behaviorally inhibited children have already had an automatic fearful control system, the advanced cognitive inhibitory control may actually lead to a rigid and inflexible overcontrol system, which puts them at higher risk for maladaptive development (White et al., 2011).

Shyness shares lots of similarities but is still different from behavioral inhibition (Rothbart &Mauro, 1990). They both refer to the anxiety and inhibition shown in novel situations. However, behavioral inhibition is used to describe a child who is nervous in both social and nonsocial situations (Degnan & Fox, 2007), whereas shyness specifically relates to social situations and involves a social-evaluation component (Rubin et al., 2011). Given this, it is important to examine the role of inhibitory control in the relation between shyness and internalizing problems, which may or may not be the same as the relation between behavioral inhibition and internalizing problems. To my knowledge, no research thus far has examined the role of inhibitory control in the relation between shyness and internalizing problems, especially during middle childhood when self-conscious shyness begins to emerge and inhibitory control just reaches the ceiling level. My research fills this gap by exploring the potential moderating effect of inhibitory control between shyness at age 6 and internalizing problems at age 9.

3. Moderating Role of Frontal EEG Asymmetry

Frontal electroencephalogram (EEG) asymmetry reflects the difference in the level of cortical activation between the left and right frontal lobes. Fox (1991, 1994) suggested that the resting frontal patterns reflect a temperament-based tendency to express either positive or negative emotion in response to stressful situation and novelty, as well as the effortful ability to regulate emotional arousal. Specifically, people with left frontal asymmetry are more likely to exhibit positive emotion and approach behaviors, and are better able to regulate their negative emotion responses. People with right frontal asymmetry are more likely to exhibit negative emotion and withdrawal behaviors, and are poorer at regulating these negative emotion responses. The theory has been supported by empirical research. For example, Hannesdottir and colleagues (2010) reported that children who exhibited right frontal EEG asymmetry in early childhood were less able to regulate their emotions at 9 years of age. Moreover, Smith and colleagues (2016) studied the relation between early frontal EEG asymmetry and later EC by taking into account children's temperament reactivity. They found that negative affectivity at both 10 months and 24 months was related to lower EC at 30-36 months only for children with right frontal asymmetry. Coan and Allen (2004) in a review paper specifically talked about the moderating role of frontal EEG asymmetry, in that it can either facilitate or diminish emotional response. Given these findings, frontal EEG asymmetry is an important physiological marker for emotion regulation.

Having left frontal asymmetry may contribute to the resilience process by overcoming negative temperament and leading to a more adaptive outcome. Fox and colleagues (1996) reported that shy children of preschool age with relative right frontal EEG asymmetry were more likely to showing internalizing problems than shy children with left frontal EEG asymmetry. Similarly, Henderson and colleagues (2001) found that negative affectivity at 9 months predicted social wariness at age 4 only for children with right frontal asymmetry at 9 months, but not for children who exhibited left frontal asymmetry during infancy. In view of this, frontal EEG asymmetry appears to play a significant role in attenuating the effect of negative temperament on maladaptive outcomes. Specifically, negative affectivity (e.g. shyness, fear) predicts internalizing problems only when children show right frontal asymmetry but not left frontal asymmetry. However, to my knowledge few researchers thus far have studied the moderating role of frontal EEG asymmetry in the relation between shyness and internalizing problems during middle childhood. My study fills this gap by exploring how children's shyness at age 6 relates to internalizing problems at age 9 giving their different frontal EEG asymmetry patterns.

3.1 Consideration of Stability of Frontal EEG Asymmetry

Stability of frontal EEG asymmetry has been studied during different developmental periods including infancy (Jones, Field, Davalos, & Pickens, 1997; Smith & Bell, 2010), toddlerhood and early childhood (Howarth, Fettig, Curby, & Bell, 2015), childhood (Vuga, Fox, Cohn, Kovacs, & George, 2008), and adulthood (Vuga et al., 2006). Jones and colleagues (1997) reported that frontal EEG asymmetry scores at 3-6 months were positively related to EEG asymmetry scores at age 3 (Pearson correlation: .66). Vuga et al. (2006) found that resting frontal EEG asymmetry showed moderate stability across 1- to 3- year interval among 49 adults with a history of unipolar depression (intraclass correlations: 0.39 to 0.61).

However, frontal EEG asymmetry tends to be less stable and vary more widely during toddlerhood and childhood. A recent studied found that frontal asymmetry was only moderately stable at the trend level from 10 to 24 months and was less stable from 24 to 36 months as well as 36 to 48 months (Howarth et al., 2015). Smith and Bell (2010) reported that among 48 infants, only 23 showed stable pattern of frontal EEG asymmetry from 10 to 24 months. Other work has noted that for 3- to 5-year-old children, frontal stability was moderate, with correlations ranging from 0.34 to 0.48 in the eyes-open condition and 0.21 to 0.31 in the eyes-closed condition. For 6- to 9-year-olds, frontal stability was low to moderate, with correlations ranging from 0 to 0.18 in the eyes-open condition and 0.19 to 0.45 in the eyes-closed condition (Vuga et al., 2008). The lower stability of frontal asymmetry during toddlerhood and childhood may be due to the continuing structural and functional brain development across the childhood years (Romine & Reynolds, 2005; Welsh & Pennington, 1998). Romine and Reynolds (2005) put forward a model of the development of frontal lobe functioning, which starts in early childhood and continues into adolescence with a decreased rate. Given this, childhood is a critical stage in studying frontal asymmetry stability. To my knowledge, there is only one research study that examined frontal asymmetry stability in children between ages 6 and 9 and that was done with small sample size, and 63% of children are offspring of depressed parents (Vuga et al., 2008; n=38). My study extended previous research by testing frontal EEG asymmetry across a 3-year interval from age 6 to age 9.

Given the potential lowered stability of frontal asymmetry during middle childhood, a better way to study the moderating role of frontal EEG asymmetry might be to examine how the stability of this early physiological marker and negative affectivity interactively predict later psychopathology. To the best of my knowledge, no research has yet studied the interactive effect of shyness and frontal EEG asymmetry stability on internalizing problems during middle childhood. In view of this, in addition to examining the effect of frontal asymmetry that is measured at specific ages, I also examined how the change patterns of frontal asymmetry moderate the relation between shyness and internalizing problems. I predicted that children who are shy and have stable right frontal asymmetry are more likely to develop internalizing problems than children who have change patterns (right to left or left to right) or stable left frontal asymmetry.

4. Current Study

Shy children are more likely to develop internalizing problems than non-shy children. There are, however, some important endogenous variables that may protect shy children from having such maladaptive developmental outcomes. Identifying and studying these protective factors can have important theoretical and clinical significance. The goal of my study was to examine which components among EC (i.e., attentional control, inhibitory control), frontal EEG asymmetry, and the stability of frontal EEG asymmetry moderate the association between shyness and internalizing problems from ages 6 to 9. It is the first study that allows us to examine the interactive effect of negative temperament and EC, as well as the interactive effect of negative temperament and frontal EEG asymmetry during middle childhood in one study. The specific hypotheses are listed as following:

1) Shyness at age 6 directly predicts level of internalizing problems at age 9.
2) Attentional control moderates the relation between shyness and internalizing problems. Specifically, it attenuates the negative effect of shyness on internalizing problems.
3) Inhibitory control moderates the relation between shyness and internalizing problems, however the direction of the moderating effect is exploratory.
4) Frontal EEG asymmetry moderates the relation between shyness and internalizing problems. Specifically, having left frontal EEG asymmetry mitigates the negative effect of shyness on internalizing problems.
5) Stability of frontal EEG asymmetry between ages 6 and 9 moderates the relation between shyness and internalizing problems. The relation between shyness and internalizing problems is strongest when children have stable right frontal asymmetry, is second strongest when children have change patterns (left-right is slightly stronger than right-left), and is weakest when children have stable left frontal asymmetry.

Method

Participants

The sample included a cohort of children from an ongoing longitudinal investigation of cognition and emotion development at 6 and 9 years of age. Of the 100 children (M= 6.80, SD= 0.59; 43 boys, 57 girls) fully participating at 6 years old, 93% were Caucasian, 1% were Asian, and 6% were of other or mixed ethnicity. When looking at parents' educational information, 87% of fathers and 96% of mothers completed some form of higher education. Among the original 100 children, 73 children (M=9.50, SD= 0.50, 33 boys, 40 girls) came back for the age 9 lab visit and finished all the tasks and questionnaires. 92% were Caucasian, 1% were Asian, and 7% were of other or mixed ethnicity. When looking at parents' educational information, 90% of fathers and 97% of mothers completed some form of higher education. Children who came back and children ho did not return were not significantly different in sex (t=.28, p>.05), race (t=.11, p>.05), parents' education level (mother t=-1.1, p>.05; father t=.40, p>.05). Children received a $ 10 gift certificate at age 6 and $20 gift certificate at age 9. Parents received a $50 gift certificate at age 6 and a $75 gift certificate as compensation for participation at age 9.

Procedures

Participants visited our lab at age 6 during the summer of 2013 and visited again at age 9 in the summer of 2016 to participant in the ongoing longitudinal research. When arriving at the research lab, children and their parents are greeted, and procedures are described by the researchers. After getting the signed consent and the verbal assent from parents and children, researchers begin to place the EEG cap on the children and administer various cognitive, socio-emotional, and academic achievement tests. Only the tasks used in my thesis research are described in this method section.

EEG Recordings

Frontal EEG asymmetry scores at ages 6 and 9 were examined for my thesis project. The baseline EEG was accomplished as the child watched a 3-minute video (opening scene from Lion King) and well as during eyes-opened and eyes-closed baselines. These are typical baseline recording conditions for children. EEG was recorded from 26 left, right, and midline scalp sites [frontal pole (Fp1, Fp2), frontal (F3, F4, Fz, F7, F8), central (C3, C4), central frontal (FC1, FC2, FC5, FC6), temporal (T7, T8), parietal (P3, P4, Pz, P7, P8), central parietal (CP1, CP2, CP5, CP6), occipital (O1, O2)]. All electrodes were referenced to Cz during the recordings. We recorded EEG using a stretch cap (Electro-Cap, Inc., Eaton, OH) with electrodes in the 10/20 system pattern. We placed a small amount of abrasive gel into each recording site and gently rub the scalp. Then conductive gel was placed in each site. Electrode impedances were measured and accepted if they were below 20 KΩ. The electrical activity from each lead was amplified using separate James Long Company Bioamps (James Long Company; Caroga Lake, NY) and bandpassed from .1 to 100 Hz. The EEG activity for each scalp electrode was displayed on the monitor of the acquisition computer. The EEG signal was digitized on-line at 512 samples per second for each channel so that the data is not affected by aliasing. The acquisition software we used is Snapshot-Snapstream (HEM Data Corp.; Southfield, MI) and the raw data were stored for later analyses.

EEG Analysis

EEG data were examined and analyzed using EEG Analysis System software developed by James Long Company (Caroga Lake, NY). First, we used Cz as the reference electrode and re-referenced the data via software to an average reference configuration. The re-referenced EEG data was artifact scored for eye movements using a peak-to-peak criterion of 100µ or greater, and artifact scored for gross motor movements using a peak-to-peak criterion200µ or greater. Only the artifact-free date was used in the following data analysis. The data were then analyzed with a discrete Fourier transform (DFT) using a Hanning window of 1 second width and 50% overlap. The power was expressed as mean square microvolts and the data were transformed using the natural log (ln) to normalize the distribution.

Power was computed at the 8-10 Hz alpha frequency band, which is inversely related to brain activity (Fox, 1994). According to research that examined the power distribution in preschool children (Marshall, Bar-Haim, & Fox, 2002), alpha corresponds to 6-9 Hz in 4-year-old children. The alpha band is typically shifted by 1-2 Hz from preschool children to school-age children based on their age-dependent peak frequencies (Niedermeyer, 1999). Therefore, alpha likely corresponds to 8-10 Hz in 6- and 9-year-old children. This frequency band has indeed been used by Forbes et al. (2006) and Vuga et al. (2008) with children in the middle childhood age range.

Frontal EEG asymmetry was calculated by subtracting the ln power at the left hemisphere (F3 & F7) from ln power at the right hemisphere (F4 & F8; Fox, 1994). Left frontal EEG asymmetry is indicated by positive EEG asymmetry values, which means greater left relative to right brain activation. Right EEG asymmetry is indicated by negative EEG asymmetry values, which means greater right to left brain activation. This is because cortical activity is inversely related to alpha power (Coan & Allen, 2004).

With respect to using frontal EEG asymmetry as a moderator, since the correlation coefficient of EEG asymmetry scores at age 6 and age 9 was larger than .2, the asymmetry score at each age was averaged to form a composite EEG asymmetry score. Regarding stability of frontal EEG asymmetry, four groups were created based on the stability of the signs of their asymmetry scores: children who showed greater left frontal activity (positive value) at both 6 and 9 years old (stable left group), children who showed right frontal asymmetry at 6 and left asymmetry at 9 (right-left change group), children who showed left frontal asymmetry at 6 and right asymmetry at age 9 (left-right change group), and children who showed greater right frontal activity (negative value) at both 6 and 9 (stable right group). Theoretically, these 4 groups represent ordinal groupings of frontal EEG asymmetry patterns that are likely to hinder or enhance the associations between shyness and internalizing.

6-year Attentional Control Tasks

Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002). The Attention Network Test was designed to measure the efficiency of three different attention networks: alerting, orienting, and executive attention. Participants were asked to indicate the direction of the central arrow as quickly and accurately as possible. Trials varied as to whether there were cues (no cue; one cue; double cue; spatial cue) and whether the center arrow was surrounded by flankers, pointing to either left or right (neutral; congruent; incongruent). The variable of interest in our study was percent accuracy of the task.

Dimension Change Card Sorting (DCCS; Zelazo, 2006). Dimension Change Card Sorting is a commonly used task to measure children's executive functioning, specifically attentional control. It requires children to sort a series of cards according to either their shape or color, so children need to shift their attention from one rule to the other. In the shape condition, children were asked to sort the cards based on shape. For example, all the "flowers" go together and all the "cars" go together. In the color condition, children were asked to sort the cards based on color. For example, all the red objects go together and all the blue objects go together. Children were instructed to finish the task in three sub-tasks: pre-switch, post-switch, and border. In the border sub-task, they were required to sort based on one rule when the card has a border, and sorting according to the other rule when there's no border. The order of shape and color were counterbalanced. The measure of interest in current study was the proportion correct in border sub-task.

9-year Attentional Control Tasks

Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002). The same Attention Network Test was administrated again at 9 years old. The variable of interest was percent accuracy of the task.

Wisconsin Card Sorting Test (WCST; Heaton, 2003). A computerized version of the Wisconsin Card Sort Task was administered to children to test their attentional control ability (Barceló, Muñoz-Céspedes, Pozo, & Rubia, 2000; Somsen, 2007). Children were instructed to sort the stimulus cards, at the bottom of the screen, into one of the four piles based the target cards at the top of the screen. Children were given the three possible ways to sort: shape, color, and number. They were told that the computer would provide feedback regarding if their choices were correct or incorrect. Their goal was to make as many correct choices as possible. The dimensions used to sort the cards changed across the task, so that participants had to change their sorting rules based on the feedback they received. The measure of primary interest in the current study was the number of total errors. This variable was reverse scored for the current study.

6-year and 9-year Inhibitory Control Tasks

Number Stroop Task (Ruffman, Rustin, Garnham, & Parkin, 2001). A computerized number Stroop task was administrated to test children's inhibitory control. There were three sections in the number Stroop task. In the control section, children were presented with a string of letters on the screen, and they asked to count the number of letters as quickly and accurately as possible. For example, if children were shown "AAA", the correct answer was 3, since there were three letters in the string. In the conflict section, children counted numbers instead of letters with the same rule as the control section. For example, if children were shown “6666”, the correct answer was 4, since there were 4 numbers in the string. The conflict section required children to inhibit the dominant tendency to say the number they see, and instead report how many numbers were on the screen. The variable of interest was the mean reaction time in the conflict condition. This variable was reverse scored for the current study.

6-year Shyness, Inhibitory Control, and Attentional Control Questionnaire

Children’s Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001) is a widely used parent report to test children’s temperament in ages 3-7 years (Rothbart et al., 2001). It measures 15 primary temperamental characteristics (e.g., sadness, anger) and 3 broad dimensions of temperament (e.g., effortful control). Parent responded on a 7-point Likert scale ranging from 1=extremely untrue of your child to 7=extremely true of your child. Three subscales in the CBQ were used in the present study: shyness (6 items; slow or inhibited approach in situations involving novelty or uncertainty), inhibitory control (6 items, the capacity to plan and to suppress inappropriate approach responses under instructions or in novel or uncertain situations), attention focusing (6 items, tendency to maintain attentional focus upon task-related channels.) In my study, the Cronbach’s alpha of shyness subscale was .87; the Cronbach’s alpha of inhibitory control subscale was .77; the Cronbach’s alpha of attention focusing subscale was .73.

9-year Shyness, Attentional Control, and Inhibitory Control Questionnaire

Early Adolescent Temperament Questionnaire-Revised (EATQ-R; Putnam, Ellis, & Rothbart, 2001) contains 62 items in 10 subscales in the parent-report version. Parents respond on a 5-point Likert scale ranging from 1=almost never true to 5=almost always true. Three subscales were used in the present study: shyness (5 items, behavioral inhibition to novelty and challenge, especially social), attention (6 items; the capacity to focus attention as well as to shift attention when desired) and inhibitory control (5 items; the capacity to plan, and to suppress inappropriate responses). Previous research showed good reliability of EATQ-R (Putnam et al., 2001), with coefficient alphas ranging from 0.65 to 0.82. In my study, the Cronbach’s alpha of shyness subscale was .91; the Cronbach’s alpha of inhibitory control subscale was .64; the Cronbach’s alpha of attention subscale was .78.

Attentional Control Composite Measure

A composite score was created to indicate attentional control at ages 6 and 9. At age 6, the first principal component among the behavioral tests (i.e., ANT, DCCS) and the questionnaire (i.e., attention focusing subscale of CBQ) explained 45% of the variance (λ= .49-.82). At age 9, the first principal component among the behavioral tests (i.e., ANT, WCST) and the questionnaire (i.e., attention subscale of EATQ) explained 49% of the variance (λ= .57-.83). Scores at each age was standardized, averaged, and standardized again to form a composite z-score. For missing data, composite scores included the remaining measure. Since the composite scores at age 6 and age 9 were correlated more than .2 (See Table 3), they were averaged to form our most reliable indicator of attentional control.

Inhibitory Control Composite Measure

A composite score was created to indicate inhibitory control at ages 6 and 9 years. At age 6, given the Stroop task and inhibitory control subscale were correlated ($r=.27$, $p<.05$); thus, the two scores were standardized, averaged, and standardized again to form a composite inhibitory control at age 6. For missing data, composite scores included the remaining measure. At age 9, given that the Stroop task and inhibitory control subscale were not correlated ($r=.14$, $p>.05$). We only used Stroop task score to measure inhibitory control. Since the IC scores at age 6 and age 9 were correlated more than .2 (See Table 3), they were averaged to form our most reliable indicator of IC.

9-year Internalizing Problems

Child Behavior Checklist (CBCL; Achenbach, 1991) is a 118-item parent report widely used to examine child's social and emotional problems from 4 to 18 years old. Each item is reported on a 3-point Likert scale ranging from 0=not true to 2=very/often true. Previous research showed good reliability and validity for the CBCL (Achenbach & Rescorla, 2001). In the present study the primary interest was the Internalizing Problem (Anxious/Depressed, Withdrawn/Depressed, and Somatic Complaints), which is reported as a composite raw score. The Cronbach's alpha of the score was .81.

Data Analysis Strategy

First, variables were examined for outliers and patterns of missing data. I verified that the outliers were true outliers and the missing data was actually missed, rather than entry errors.

1) Hypothesis 1 was shyness at age 6 directly predicts internalizing problems at age 9.

I tested Hypothesis 1 by running a regression analysis with age-6 shyness as independent variable and shyness as dependent variable.

2) Hypothesis 2 was attentional control moderates the relation between shyness and internalizing problems. Specifically, it attenuates the negative effect of shyness on internalizing problems.

I tested Hypothesis 2 by conducting a hierarchical multiple regression analysis. In order to eliminate problems of collinearity, the predicted continuous variables (i.e. shyness and attentional control) was standardized before doing multiple regression. The interaction term (i.e. shyness*attentional control) was created by multiplying the standardized scores. The independent variables were entered in the first step, following that the interaction term was entered in the second step. Given the difficulty in identifying significant interactive term in social science, we follow the rule that *p* value lower than .10 indicates the existence of moderating effect (McClelland & Judd, 1993). If there was a moderating effect, I used mean and mean plus and minus one standard deviation of the moderators to plot each of the simple slopes (Aiken & West, 1991).

3) Hypothesis 3 is inhibitory control moderates the relation between shyness and internalizing problems, however the direction of the moderating effect is exploratory.

The method for testing Hypothesis 3 was same as Hypothesis 2.

4) Hypothesis 4 is frontal EEG asymmetry moderates the relation between shyness and internalizing problems. Specifically, having left frontal EEG asymmetry mitigates the negative effect of shyness on internalizing problems.

The method for testing Hypothesis 4 was same as Hypothesis 2.

5) Hypothesis 5 is stability of frontal EEG asymmetry moderates the relation between shyness and internalizing problems. The relation between shyness and internalizing problems is strongest when children have stable right frontal asymmetry, is second strongest when children have change patterns (left to right is slightly stronger than right to left), and is weakest when children have stable left frontal asymmetry.

Four groups (stable left, right-left, left-right, stable right) that represent the ordinal groupings of frontal EEG asymmetry patterns were binary coded. In order to compare any two groups among the four groups in simple slope difference, four coded variables (D1, D2, D3, D4) were created. Stable left was coded as 0, 0, 0, 1. Right to left was coded as 1, 0, 0, 0. Left to right was coded as 0, 1, 0, 0. Stable right was coded as 0, 0, 1, 0. Three multiple regression analyses were performed. In the first regression model, stable left was the control group. Shyness was entered first, followed by entering the three coded variables that were all coded 0 on stable left group, and the corresponding interaction terms was entered in the third step. The first model allowed us to compare the simple slope of stable left group to the simple slopes of other three groups. In the second model, right-left was the control group. Shyness was entered first, followed by entering the three coded variables that were all coded 0 on right-left group, and the corresponding interaction terms were entered in the third step. The second model allowed us to compare the simple slope of right-left group to the simple slopes of other three groups. In the third model, left-right was the control group. Shyness was entered first, followed by entering the three coded variables that were all coded 0 on left-right group, and the corresponding interaction terms were entered in the third step. The third model allowed us to compare the simple slope of left-right group to the simple slopes of other three groups. There was no need to conduct a fourth regression analysis with stable right group as the control group, since it had already been compared with all other three groups. In each hierarchy regression analysis, if any one of the interaction term was significant (i.e., $p<.10$), it indicated the model with interaction term is the best fit model.

Results

Preliminary Analysis

Descriptive statistics are shown in Table 1 and Table 2 for age 6 and age 9 separately. ANT and Stroop outliers were handled through winsorization, such that scores that were more than 3 SD from the mean were replaced by the next closest score. This technique was applied to 1 outlier for ANT and 1 outlier for Stroop. The scores with winsorization were used to create composite z-scores.

Regression Analysis

Contradictory to my hypothesis, shyness at 6 years old did not predict IP at 9 years old (Table 4). Although the association was not significant, I continued to test whether IC, AC, Frontal EEG asymmetry (FA), and FA stability moderated the correlation between age 6 shyness and age 9 IP. Regression analysis indicated that IC did not moderate the association between shyness and IP (See Table 5). AC did not moderate the association between shyness and IP (See Table 6). FA did not moderate the association between shyness and IP (See Table 7). The stability of FA did not moderate the association between shyness and IP (See Table 8, 9, &10). For IC, although the interaction terms were significant, the whole models were not significant. Thus, I cannot interpret the moderation given the non-significant overall model.

In order to determine out how many more participants I would need to reach the significance level for the IC whole model, I conducted power analysis. Effect size (i.e., Cohen's f^2) was computed using the squared multiple correlation (i.e., R^2). Cohen's f^2 was .11, given .05 α error and .8 power, the total sample size needed was 104.

Post hoc Analysis

Although age 6 shyness didn't directly predict age 9 IP, there was an indirect association between shyness at 6 years old and IP at 9 years old through shyness at 9 years old (95 % BC bootstrap CI: lower limit = .75, upper limit = 1.94). Given that shyness at age 9 predicted IP at age 9, I further tested whether AC, IC, and FA at age 9 moderated the association between shyness and IP at 9 years old. There was a significant interaction term between shyness and IC (See Table 12), which indicated that IC moderated the association between shyness and IC. Shyness significantly predicted IP when children had low and medium levels of IC, but not for high IC (See Figure 1). There was a significant interaction term between shyness and AC (See Table 13), which indicated that IC moderated the association between shyness and AC. Shyness significantly predicted IP when children had low and medium levels of AC, but not for high AC (See Figure 2). FA did not moderate the correlation between shyness and IP (See Table 14).

Discussion

Hypothesized Analyses

The primary goal of my thesis study was to examine the predictive effect of shyness on IP, as well as to examine IC, AC, FA, and the stability of FA as potential factors that moderate the temperament-IP association. Contradictory to my hypothesis, shyness at age 6 failed to predict IP at age 9 directly. None of the hypothesized moderators affected the association between age 6 shyness and age 9 IP. The results were inconsistent with previous findings showing that shyness reliably predicts IP longitudinally (Rothbart &Mauro, 1990; Brumariu & Kern, 2013; Leve, Kim, & Pears, 2005). However, age 6 shyness indirectly predicted age 9 IP through age 9 shyness, which demonstrated the concurrent association between shyness and IP (Coplan et al., 2008). AC and IC moderated the association between age 9 shyness and age 9 IP. Shyness was significantly correlated with IP when children have low and medium AC, but not correlated when children had high AC. Similarly, shyness was significantly correlated with IP when children have low and medium IC, but not correlated when children had high IC.

Shyness failed to directly predict IP across a three-year span. The finding was in line with some previous studies indicating that the longitudinally predictive effect of shyness on IP may be modest during during middle childhood. For example, parent reported and teacher reported shyness measured at 6 years old was not directly associated with IP measured four years later (i.e., 10 years old). However, there was an indirect association between age 6 shyness and age 10 IP through age 8 and age 10 shyness (Eggum et al., 2012). Moreover, Prior and colleagues (2000) found that the association between childhood shyness and adolescent anxiety disorder was modest in a large community sample. Most shy children did not develop an anxiety disorder and most adolescents with anxiety disorders were not shy when they were young. Although the concurrent correlation between shyness and IP was robust in previous research, future research may want to further study if shyness predicts IP longitudinally using both epidemiological and community samples and across different age spans.

AC, IC, FA, and the stability of FA did not moderate the association between age 6 shyness and age 9 IP. One possible reason is that shyness at age 6 did not significantly contribute to IP at age 9, so the overall explained variance relative to the error variance was small, which resulted in a non-significant overall model. Or it might because the effect size of moderation across a three-year span was small, so larger sample size was needed to reach the power level. For example, results suggested that 31 more participants were needed to make the IC moderation model significant. So it would be ideal to examine the moderating effect of the hypothesized variables in a larger sample size.

Post-hoc Analyses

Age 9 shyness predicts age 9 IP

Results indicated that shyness at age 9 predicted IP at age 9. Children with high level of shyness are more likely to have IP compared with children with low level of shyness at 9 years old. According to A.H. Buss (1986a, 1986b), there are two different subtypes of shyness, which are fearful shyness and self-conscious shyness. The origins and elicitors of each are different. Fearful shyness refers to reactions, such as crying, wariness, distress, and escaping behaviors, in the response to social novelty. Self-conscious shyness is elicited by being the center of attention, being conspicuous, or being psychologically unprotected. Different from fearful shyness, it manifests as embarrassment and social anxiety (Buss, 1986a, 1986b). It is important to distinguish between two types of shyness in order to study which is associated with later anxiety and other maladaptive developmental outcomes (Buss, 1986a). Buss argued that fearful shyness appears earlier in development and that self-conscious shyness appears later, with the transition period being 4 to 5 years old.

Research by Crozier and Burnham (1990) also indicated that fearful shyness is developmentally earlier than self-conscious shyness, but that the latter type of shyness does not seem to develop until the child is at least 7 or 8 years old. Self-conscious shyness is predicted by earlier fearful shyness, but does not replace it. For children ages 10-11, Crozier and Burnham (1990) reported that shyness was associated with meeting novel people and situations, as well as with being conspicuous and embarrassed. For children at ages 5 and 6, shyness was not associated with being focused on or being conspicuous. And only 20 percent of 7- to 8-year-old children reported this association. A specific example of an 11-year-old boy's protocol demonstrates this point: "I feel a lot more shy now than when I was younger ... you're not really bothered about anything when you are younger, you don't really care if people are watching you, or what they might be thinking of you" (Crozier & Burnham, 1990, p.183). The appearance of self-conscious shyness may be correlated with self-reflective ability, which is absent at age 6 and manifests at age 8 (Selman & Byrne, 1974). In other words, compared with age 6 children, age 9 children are better able to take others' perspectives, which may serve as a nonnegligible elicitor of shyness. Thus, shyness may be very different at age 6 and age 9. Specifically, there are more stimuli that can elicit shyness in 9 year olds. Also the degree of shyness at 9 years might be more intense than shyness at age 6, and thus put children at higher risk for developing IP.

Moderating role of AC

Given that there was a significant association between age 9 shyness and age 9 IP, I further tested whether AC, IC, and FA at age 9 moderated this association in post-hoc analyses. AC moderated the correlation between shyness and IP. Specifically, it attenuated the negative effect of shyness on IP. This finding was supported by previous research. For example, AC moderated the association between behavioral inhibition and various dimensions of IP. Specifically, AC mitigated the negative effect of behavioral inhibition on IP (Sportel, Nauta, de Hullu, de Jong, & Hartman, 2011).

This might relate to the attentional bias showed by shy children. Pérez-Edgar and Fox (2005) found that shy children tended to pay attention to the negative cues presented during the attention task. Shy and non-shy children also differed in how to response to emotional stimuli that is indicated by the P1 event-related potential (ERP) component. Individuals who were in the high-shy group showed reduced P1 amplitude for fearful faces compared to neutral faces. However, responses might be different if shy children had good AC. Derryberry and Reed (2002) found that anxious individuals who had poor attentional control showed threat bias whereas those with good control were better able to shift their attention from the threatening stimuli. Thus, AC eliminated the attentional bias of children with high level of shyness, and in turn reduced the risk for generating IP.

Moderating role of IC

My study extended previous research by showing that IC moderated the association between shyness and IP. Specifically, it mitigated the negative effect of age 9 shyness on age 9 IP. The role of IC in the development of IP remained unclear in previous research. Although there are substantial studies reporting that high IC protects children from generating IP (Kertz, Belden, Tillman, & Luby, 2015; Rhoades, Greenberg, & Domitrovich, 2009), these studies fail to take into account children's temperament reactivity. When considering child temperament, high IC actually exacerbated the positive association between behavioral inhibition and anxiety in some reports (White et al., 2011; Osher et al., 2007). Behavioral inhibition could be seen as an extreme type of shyness given it refers to intense fearful reactions when facing both social and nonsocial novelty. Although high IC and shyness might lead to an inflexible and rigid over-control system, just like what happens with behavioral inhibition reported in previous studies, the findings of the current research demonstrated that IC plays a protective role for children with high level of shyness. To the best of my knowledge, this is the first study examining the interactive effect of shyness and IC on IP during middle childhood.

AC and IC are two major cognitive processes that facilitate the increasing ability to control emotional reactivity (Fox & Calkins, 2003). The three attention system: the orienting, vigilance, and executive attention systems as important cognitive control systems underlie the development of emotional control (Rothbart, Posner, & Hershey, 1995). Thus, children with better attentional control are better able to control their emotions. Similar to AC, IC plays a significant role in emotional regulation. It allows individuals to inhibit the tendency toward an attractive stimulus in order to avoid the negative or unpleasant outcomes. Carlson and Wang (2007) reported that inhibitory control helps children to develop in a more adaptive way by enabling them to regulate the expression of negative emotions using more effective coping strategies. The findings of my study demonstrate that greater AC and IC, which indicates higher emotional control capacity, attenuate the association between shyness, as a specific dimension of negative affectivity, and IP during middle childhood.

Moderating role of Frontal EEG Asymmetry

My thesis study failed to find the moderating effect of FA between shyness and IP during middle childhood. Previous studies that have reported the moderating role of left FA on IP were focused on infancy (Smith et al., 2016; Henderson et al., 2001) and preschool ages (Fox et al., 1996). Thus the moderating effect of FA may be age-related. When children become older, the protecting effect of being left FA may be no longer enough to protect against the maladaptive and well-established behavioral patterns of being shy. So being left FA does not give children advantages.

On the other hand, Fox and colleagues (1996) explained that the cognitive control abilities underlying emotion regulation are mediated by frontal lobes. Many of these cognitive control skills are related to verbal ability and analytic abilities, which are all considered as left frontal tasks. So children with left FA may develop better coping strategies to deal with distress, whereas children with right FA may have fewer or less-developed language-mediated coping strategies, and thus are less able to regulate negative emotions. However, individual difference in using language-mediated coping strategies might decrease as children's language ability continues to develop. So being right FA might not indicate children have poorer coping strategies during middle childhood and afterwards. Future research may want to further study the moderating role of FA in middle childhood and older ages.

Strengths and Limitations

My study had several methodological strengths. First, I incorporated maternal reports, behavioral tasks, and physiological measures. Using multiple measures enhanced the test of my hypotheses. Second, I used multiple, age-appropriate IC and AC tasks at each age to cover wide ranging skills, rather than focusing on single aspects of IC and AC. Third, the use of community sample allows for generalization of my findings to other typically developing children.

Although my study had such strengths, some limitations should also be mentioned. First, shyness and IP were measured by maternal report. Although parental report may be considered as a limitation of study, it also might be an advantage. Maternal reports measure child behavioral patterns across different natural environments. This multi-context measure may be a better way to reflect child behaviors and thus enhance the ecological validity of the findings. Ideally, future research may want to integrate maternal report and observations to measure shyness as well as maladaptive behaviors in a more comprehensive way. Second, due to the limitation of the analytic methods, children without complete data were dropped from the analysis. It would be ideal to use other statistical analysis techniques, for example structural equation models, to deal with missing values in order to take advantage of all available information on all participants. As I continue to take coursework, I will be able to apply these techniques in my future research.

Conclusion

Notwithstanding these limitations, my thesis research project provides clear evidence that shyness at age 9 is positively associated with IP at age 9. In addition, AC and IC at age 9 moderate the shyness-IP association. Shy children with greater AC and IC are at lower risk for having IP. My study also provides evidence that age 9 shyness might differ from age 6 shyness regarding what type of shyness is characteristic of children at different ages. It highlights the importance of potentially distinguishing between fearful shyness and self conscious shyness in studying their relations with socio-emotional development. Future research may want to further examine how each type of shyness is associated with IP concurrently and longitudinally, as well as what intrinsic and extrinsic influences moderate the longitudinal associations.

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Table 1

Descriptive Statistics at age 6

	Mean	Minimum	Maximum	SD
Shyness_CBQ	4.07	1.00	6.83	1.31
IC	.00	-2.90	1.85	1.00
IC_CBQ	4.97	2.33	6.67	1.10
Stroop	3628.06	1787.64	6837.20	1245.78
AC	.00	-2.32	1.87	1.00
AC_CBQ	5.04	2.17	6.83	1.01
ANT	88.23	59	100	10.32
DCCS	.69	.42	1.00	.18
FA	.02	-.47	.84	.27

Note. IC and AC are standardized z-score. Stroop and ANT are scores with winsorization.

Table 2

Descriptive Statistics at age 9

	Mean	Minimum	Maximum	SD
Shyness_EATQ	2.56	1.00	4.80	1.01
IC_EATQ	3.72	2.40	5.00	.59
Stroop	2262.30	1269.39	4118.96	626.90
AC	.00	-2.79	1.77	1.00
AC_EATQ	3.22	1.50	4.83	.78
ANT	95.51	76	100	4.45
WCST	23.18	7.00	46.00	9.15
FA	-.00	-.83	.79	.30
IP	6.75	0	24	5.61

Note. AC is standardized z-score.

Table 3

Correlation table

	Shyness_6	Shyness_9	IC_6	AC_6	IC_9	AC_9	FA_6	FA_9
Shyness_9	.53*							
IC_6	.24*	.08						
AC_6	.30*	.19	.59*					
IC_9	.22	-.05	.48*	.19				
AC_9	.08	-.12	.44*	.42*	.34*			
FA_6	-.03	-.09	-.16	-.13	.04	-.28*		
FA_9	.01	.02	.08	.06	.16	-.12	.25*	
IP_9	.13	.45*	-.05	.17	-.06	-.22	-.09	.12

Note. *$p<.05$

Table 4

Regression model: Shyness at age 6 predicts internalizing problems at age 9

	b	β	SE	t	*p*
Shyness_6	.75	.13	.66	1.13	.26

Note. R^2=.02, $F_{(1,71)}$=1.28, *p*=.26.

Table 5

Moderation model: IC as a moderator between shyness at age 6 and internalizing problems at age 9

	b	β	SE	t	*p*
Step1					
Shyness_6	.90	.16	.69	1.31	.20
IC	-.67	-.10	.80	-.85	.40
Step2					
S_IC	-1.69	-.27	.73	-2.30	.03*

Note. Step1 R^2=.03, $F_{(2,70)}$= 1.00, p=.38; Step2 ΔR^2=.07, $\Delta F_{(1,69)}$=5.28, p=.03.

*p<.05.

Table 6

Moderation model: AC as a moderator between shyness at age 6 and internalizing problems at age 9

	b	β	SE	t	*p*
Step1					
Shyness_6	.83	.15	.68	1.21	.23
AC	-.43	-.06	.81	-.53	.60
Step2					
S_AC	-1.17	-.18	.80	-1.46	.15

Note. Step1 R^2=.02, $F_{(2,70)}$=.77, p=.47; Step2 ΔR^2=.03, $\Delta F_{(1,69)}$=2.14, p=.15.

Table 7

Moderation model: Frontal EEG asymmetry as a moderator between shyness at age 6 and internalizing problems at age 9

	b	β	SE	t	*p*
Step1					
Shyness_6	.75	.13	.66	1.13	.26
FA	.75	.03	2.97	.25	.80
Step2					
S_FA	-6.38	-.20	3.87	-1.65	.10

Note. Step1 R^2=.02, $F_{(2,70)}$=.66, *p*=.52; Step2 ΔR^2=.04, $\Delta F_{(1,69)}$=2.71, *p*=.10.

Table 8

Moderation model: Frontal EEG asymmetry stability as a moderator between shyness at age 6 and internalizing problems at age 9 (Stable Left as the control group)

	b	β	SE	t	*p*
Step1					
Shyness_6	.75	.13	.66	1.13	.26
Step2					
D1	1.99	.14	1.99	1.00	.32
D2	.39	.03	1.85	.21	.84
D3	.82	.07	1.76	.47	.64
Step3					
S_D1	2.56	.20	1.98	1.29	.20
S_D2	2.04	.20	1.82	1.12	.27
S_D3	2.14	.16	2.10	1.02	.31

Note. Step1 R^2=.02, $F_{(1,71)}$=1.28, *p*=.26; Step 2 ΔR^2=.02, $\Delta F_{(3,68)}$=.35, *p*=.79; Step 3 ΔR^2=.03, $\Delta F_{(3,65)}$=.73, *p*=.54.

Table 9

Moderation model: Frontal EEG asymmetry stability as a moderator between shyness at age 6 and internalizing problems at age 9 (Right to Left as the control group)

	b	β	SE	t	*p*
Step1					
Shyness_6	.75	.13	.66	1.13	.26
Step2					
D2	-1.17	-.09	2.03	-.58	.57
D3	-.76	-.06	1.95	-.39	.70
D4	-1.47	-.12	1.95	0.75	.45
Step3					
S_D2	-.28	-.03	1.95	-.14	.89
S_D3	-.17	-.01	2.21	-.08	.94
S_D4	-2.26	-.20	1.97	-1.15	.26

Note. Step1 R^2=.02, $F_{(1,71)}$=1.28, *p*=.26; Step2 ΔR^2=.01, $\Delta F_{(3,68)}$=.21, *p*=.89; Step 3 ΔR^2=.03, $\Delta F_{(3,65)}$=.59, *p*=.62.

Table 10

Moderation model: Frontal EEG asymmetry stability as a moderator between shyness at age 6 and internalizing problems at age 9 (Left to Right as the control group)

	b	β	SE	t	*p*
Step1					
Shyness_6	.75	.13	.66	1.13	.26
Step2					
D1	1.76	.12	2.08	.85	.40
D3	.60	.05	1.89	.32	.75
D4	-.11	-.01	1.86	-.06	.95
Step3					
S_D1	.84	.07	2.00	.42	.68
S_D3	.42	.03	2.11	.20	.84
S_D4	-1.66	-.15	1.86	-.90	.37

Note. Step1 R^2=.02, $F_{(1,71)}$=1.28, *p*=.26; Step2 ΔR^2=.01, $\Delta F_{(3,68)}$=.34, *p*=.80; Step 3 ΔR^2=.03, $\Delta F_{(3,65)}$=.60, *p*=.62.

Table 11

Regression model: Shyness at age 9 predicts internalizing problems at age 9

	b	β	SE	t	*p*
Shyness_9	2.55	.45	.60	4.25	.00*

Note. R^2=.21, $F_{(1,70)}$=18.05, p<.05. *p<.05.

Table 12

Moderation model: IC as a moderator between shyness at age 9 and internalizing problems at age 9

	b	β	SE	t	*p*
Step1					
Shyness_9	2.53	.45	.61	4.16	.00*
IC	-.25	-.04	.61	-.41	.68
Step2					
S_IC	-1.19	-.20	.64	-1.87	$.07^{\dagger}$

Note. Step1 R^2=.21, $F_{(2,68)}$=8.84, *p*=.00; Step 2 ΔR^2=.04, $\Delta F_{(1,67)}$=3.49, *p*=.07.

*p<.05, $^{\dagger}p$<.10.

Table 13

Moderation model: AC as a moderator between shyness at age 9 and internalizing problems at age 9

	b	β	SE	t	*p*
Step1					
Shyness_9	2.44	.43	.60	4.07	.00*
AC	-1.34	-.16	.88	-1.53	.13
Step2					
S_AC	-1.10	-.19	.61	-1.80	$.08^{\dagger}$

Note. Step1 R^2=.23, $F_{(2,69)}$=10.37, *p*=.00; Step 2 ΔR^2=.27, $\Delta F_{(1,68)}$=3.24, *p*=.08.
**p*<.05, †*p*<.10.

Table 14

Moderation model: Frontal EEG asymmetry as a moderator between shyness at age 9 and internalizing problems at age 9

	b	β	SE	t	*p*
Step1					
Shyness_9	2.56	.46	.60	4.26	.00*
FA	2.01	.11	2.01	1.00	.32
Step2					
S_FA	2.58	.15	1.94	1.33	.19

Note. Step1 R^2=.22, $F_{(2,67)}$=9.69, p=.00; Step 2 ΔR^2=.02 $\Delta F_{(1,66)}$=1.77, p=.19.

*p<.05.

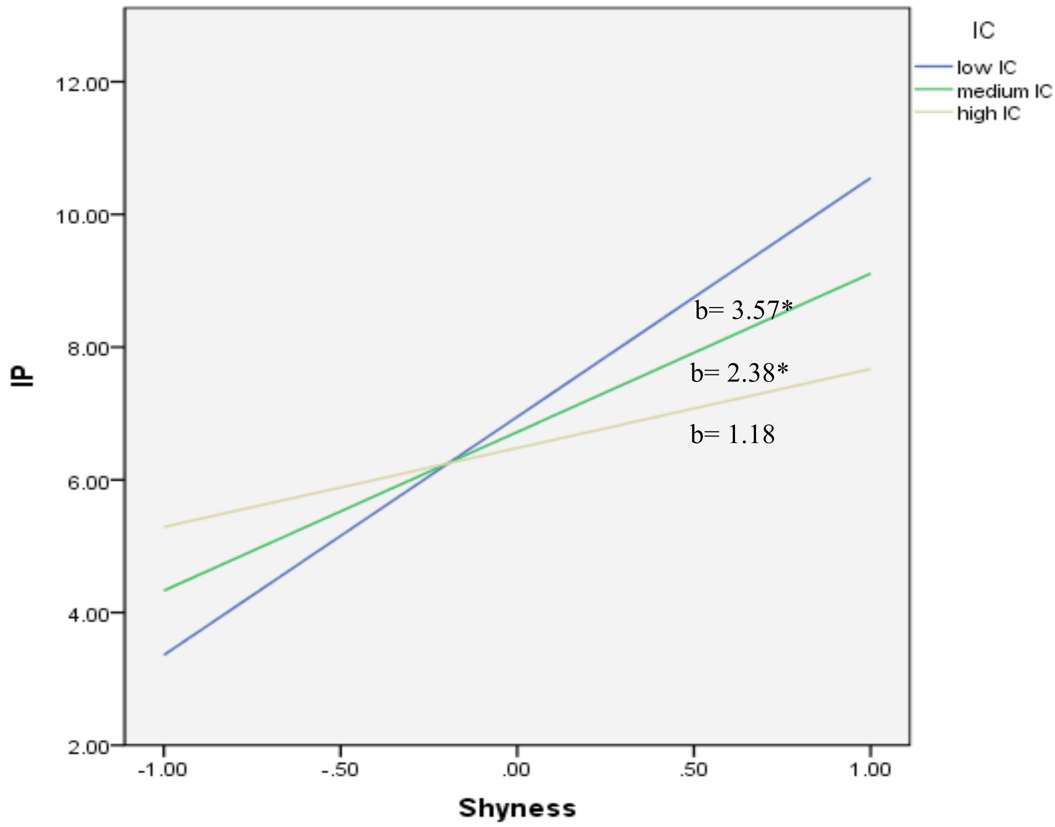

Figure 1. The effect of shyness on internalizing problems at different levels of inhibitory control. Low= mean-1SD; medium=mean; high=mean+1SD. **p*<.05.

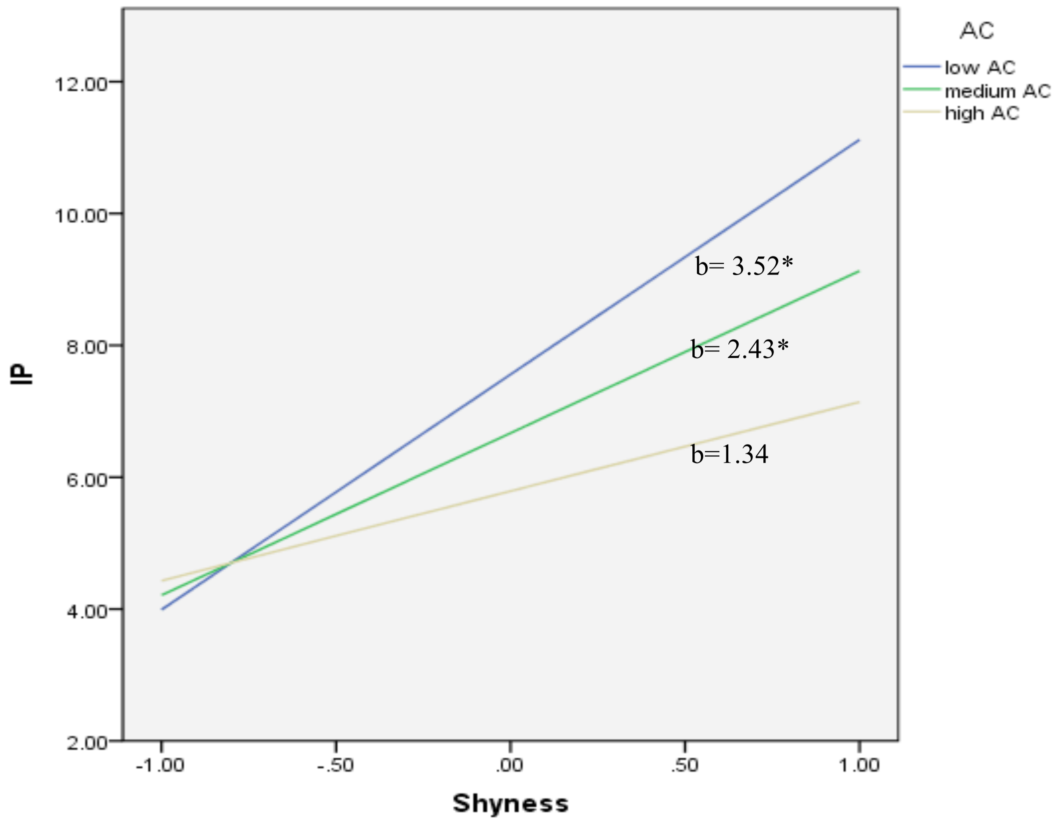

Figure 2. The effect of shyness on internalizing problems at different levels of attentional control. Low= mean-1SD; medium=mean; high=mean+1SD. **p*<.05

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MEMORANDUM

DATE: May 9, 2016

TO: Martha Ann Bell, Cynthia Lea Smith, Jungmeen Kim-Spoon, Kirby Deater-Deckard, Leslie Ann Patton, Tashauna Louise Blankenship, Alleyne Ross, Ran Liu, Cassondra Mayve Eng, Leigh Foster Bacher, et. al.

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Psychobiology of Cognitive Development in Middle Childhood

IRB NUMBER: **12-947**

Effective May 9, 2016, the Virginia Tech Institution Review Board (IRB), at a convened meeting, approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As: **Full Review**
Protocol Approval Date: **November 12, 2015**
Protocol Expiration Date: **November 11, 2016**
Continuing Review Due Date*: **September 26, 2016**
*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?
11/12/2012	12054209	NIH, Center for Scientific Review	Compared on 11/12/2012

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.