The Pennsylvania State University

The Graduate School

INHIBITORY CONTROL AS A RISK FACTOR FOR INTERNALIZING BEHAVIORS IN BEHAVIORALLY INHIBITED CHILDREN: A MOBILE EYE TRACKING INVESTIGATION

A Thesis in

Psychology

by

Kelley E. Gunther

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

December 2019

The thesis of Kelley E. Gunther was reviewed and approved* by the following:

Koraly Pérez-Edgar
McCourtney Professor of Child Studies
Professor of Psychology
Thesis Adviser

Kristin Buss
Professor of Psychology and Human Development and Family Studies

Cyntha L. Huang-Pollock
Professor of Psychology

Mel Mark
Professor of Psychology
Head of the Department of Psychology

*Signatures are on file in the Graduate School

ABSTRACT

Behavioral inhibition (BI) is a temperamental profile and a well-documented risk factor for internalizing behaviors like social anxiety. However, not all children go on to be highly anxious. Previous research suggests that levels of inhibitory control may moderate the relation between BI and maladaptive socioemotional trajectories, such as anxiety. However there are competing perspectives regarding whether high inhibitory control may act as a protective (Attentional Control Theory) or risk factor (Dual Processing Perspective) for internalizing behaviors, and whether this relation may vary as a function of BI. Furthermore, prior work suggests that naturalistic measures of inhibitory control and corresponding patterns of visual attention may further elucidate these relations. To test these perspectives, the present study examined both behavioral responses and patterns of naturalistic visual attention during an inhibitory control task, where a child took turns with an experimenter choosing blocks from a tower, as moderators in the relation between BI and internalizing behaviors.

Participants included a sample of 37 children ranging from 5 to 7 years of age. The Behavioral Inhibition Questionnaire (BIQ) was used to both over-sample for BI children as well as measure BI as a continuous variable in analyses. The Child Behavior Checklist (CBCL) was also used to measure count of internalizing behaviors in these children. We found that metrics of gaze and behavior were significantly related, suggesting interrelations between visual attention and overt behavior during a naturalistic inhibitory control task. Behavioral metrics computed did not significantly moderate the relation between BI and internalizing symptoms. While our naturalistic visual attention metrics also did not significantly moderate the relation between BI and internalizing behaviors, we did find a significant main effect of proportion of gaze to the blocks in the game, where allocation of gaze to the blocks was inversely related to reported count of internalizing symptoms. These findings provide support for both the Attentional Control Theory and the Dual Processing perspective, while also emphasizing the importance of ecologically valid measures of visual attention.

TABLE OF CONTENTS

LIST OF FIGURES vii

LIST OF TABLES viii

ACKNOWLEDGEMENTS ix

Chapter 1 - Introduction 1

Behavioral Inhibition and Orienting Attention 2

Executive Functioning and Executive Attention 5

Associations Between Orienting Attention and Executive Attention 6

Theoretical Perspectives on the Interplay Between Temperament, Psychopathology, Orienting Attention, and Executive Attention 8

Considerations in Measurement 18

The Current Study 21

Chapter 2 - Methods 25

Sample 25

Procedure 27

Data Processing 30

Chapter 3 - Results 36

Behavioral Data **36**

Mobile Eye Tracking Data **40**

Chapter 4 - Discussion **45**

References **51**

LIST OF FIGURES

Figure **1-1**: Bullseye overlaid on scene view to indicate location of gaze. .... **Error! Bookmark not defined.**3

Figure **2-1**: Histogram depicting distribution of number of skipped turns in the sample.. 37

Figure **3-1**: Histogram depicting distribution of number of verbal prompts in the sample. 38

Figure **4-1**: Histogram depicting distribution of latency to first verbal prompt in the sample. 38

Figure **5-1**: Histogram depicting distribution of proportion of gaze to Jenga blocks in the sample........ 40

Figure **6-1**: Histogram depicting distribution of proportion of gaze to the experimenter in the sample 41

Figure **7-1**: Histogram depicting distribution of proportion of gaze to the room in the sample 41

Figure **8-1**: Scatterplot depicting main effect of attention to toy on internalizing symptoms 45

LIST OF TABLES

Table **1-1**: Mean and Standard Deviation of the duration of each task trial in seconds......29

Table **2-1**: Descriptive statistics for behavioral data......37

Table **3-1**: Spearman's correlation table showing interrelations between demographic and behavioral variables of interest.. 39

Table **4-1**: Descriptive statistics for mobile eye tracking data......40

Table **5-1**: Spearman's correlation table showing interrelations between demographic, behavioral, and visual attention variables of interest......43

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE1255832 (to KEG), and by R21 MH111980 (to KPE).

I would like to thank my advisor, Dr. Koraly Pérez-Edgar, for her endless support and guidance through this project and others. I cannot imagine a better lab to call "home" through this process.

I would also like to thank Dr. Kristin Buss and Dr. Cynthia Huang-Pollock for their insightful comments and questions through both the thesis proposal and defense, prompting me to think more critically about this research and making me a stronger scientist.

I'd finally like to express my appreciation for friends and family, near and far, for their unconditional support, particularly Eileen Ser for providing a couch and abundant coffee in Denver where I was able to write a large portion of this document. Grad school would be impossible without such a strong support system, so for this I am infinitely thankful.

Chapter 1

Introduction

Behavioral inhibition (BI), a temperamental profile, is marked by reticence to novel contexts (Kagan et al., 1988) reflected on both a behavioral and physiological level. Behaviorally inhibited individuals are particularly reticent to novelty in social situations (Kagan et al., 1988; Rubin et al., 2002). BI is also our best-documented individual risk factor for anxiety in childhood and adolescence (Chronis-Tuscano et al., 2009; Clauss & Blackford, 2012; Hirshfeld et al., 1992). However, researchers continue to study the different pathways of both risk and resilience that may stem from BI, as not all children go on to be highly anxious (Degnan & Fox, 2007). Differences in levels of inhibitory control, an executive function, present as a candidate individual difference to better understand pathways to anxiety. However, where high inhibitory control is conventionally thought to lead to favorable developmental outcomes, it may operate differently in BI children as compared to children who do not fit this temperamental profile.

This thesis will focus on two broad types of attention, orienting attention and executive attention (Posner & Peterson, 1990), with an emphasis on how they may manifest specifically in visual attention. Orienting attention is described as a more automatic, stimulus-driven component of attention (Posner & Peterson, 1990). On the other hand, executive attention is a more voluntary, top-down component that can override more automatic responses, and includes inhibitory control (Posner & Peterson, 1990). We will review relations in the literature between BI and orienting attention, as well as relations between executive functioning, specifically inhibitory control, and executive attention. We will also review competing theoretical models of how orientating attention and executive attention may interact, and how these interactions may differ in the context of different temperaments. Empirically, we will focus on a subset of the theorized relations. In particular, we will utilize novel methodology to examine how levels of inhibitory control may covary with patterns of naturalistic visual attention, and test whether measures of visual attention moderate the relation between BI and internalizing symptoms by reflecting the way in which a child manages attention during an inhibitory control task.

Behavioral Inhibition and Orienting Attention

Attention biases to threat. Behavioral inhibition is fairly stable across the lifespan, and high, stable BI is a strong risk factor for internalizing difficulties, such as social anxiety disorder (Chronis-Tuscano et al., 2009; Hirshfeld et al., 1992). An attention bias to threat can be defined as an automatic, preferential, and prolonged allocation of attentional resources to a stimulus considered threatening to one's wellbeing (Henderson et al., 2015; Roy et al., 2008). An attention bias to threat is one component of the wide profile of BI markers, wherein BI individuals will disproportionately attend to threatening emotional stimuli on both a behavioral and neural level (Pérez-Edgar et al., 2010a; Shackman et al., 2009). Attention bias, particularly to threat, is also considered a characteristic of both pediatric and adult anxiety disorders (Roy et al., 2008) and may be part of the etiology of anxiety disorders (Lonigan et al., 2004).

The orienting attention network in development. The brain network associated with orienting attention, which includes attention biases to threat, is early-emerging and attributed to brain areas such as the superior colliculus, inferior/superior parietal lobe, and the frontal eye fields. Examples of automatic behaviors that the network governs include orienting to stimuli, signal detection, and vigilance (Cuevas & Bell, 2014; Posner & Peterson, 1990). Stimulus-driven looking behaviors such as looking duration predict more advanced abilities such as visual disengagement from as early as infancy – "long looking" infants may show longer disengagement latencies, with the inverse suggested for "short-looking" infants (Colombo, 1995; Cuevas & Bell, 2014).

A study by Frick, Colombo, and Saxon (1999) categorized infants as either "longer looking" or "shorter looking" based on the longest amount of time they continuously fixated on an image of a female face, followed by a checkerboard image. Following this classification, infants were tested on a visual disengagement paradigm, in which infants were presented with a central diamond pattern, followed by a peripheral target either concurrently, in competition with the central target, or sequentially, not in competition with the central target. "Longer looking" infants were slower to visually disengage from the central diamond-pattern stimulus when presented with a peripheral diamond stimulus concurrently, suggesting that infants displaying longer looking duration may also display slower disengagement latencies. This finding is evidence that as early as infancy, individuals differ in basic looking behaviors. Furthermore, these lower-level, stimulus-driven looking behaviors such as general looking time can predict more goal-directed functions of visual orienting, such as disengagement from one stimulus to attend to another (Frick et al., 1999)

Early in development, visual attention and the orienting attention network itself may vary as a function of individual differences in temperamental reactivity (Rothbart et al., 2011). During infancy, continual orienting to a novel stimulus in an experimental setting may be a source of distress for a child. However, this distress may be eased by the ability to disengage and subsequently orient to a "distractor" stimulus. This ability to flexibly orient is positively associated with infant soothability and negatively associated with negative emotionality (Rothbart et al., 2011). In more naturalistic situations, infants may self-soothe by disengaging from their source of distress or looking to something familiar like their mother (Rothbart et al., 1992). Flexible orienting can therefore serve as a regulatory mechanism from early in development, allowing individuals to deploy attention in a way that reduces distress.

Visual attention patterns during infancy may also interact with temperamental predispositions to predict socioemotional development. In a study by Pérez-Edgar and colleagues (2010b), sustained attention was measured in a sample of 9-month-olds recruited for infant reactivity at 4 months. Temperament was measured at multiple time points up to 7 years, as well as social discomfort during adolescence. The study found that low sustained attention predicted increasing levels of BI longitudinally. Additionally, there was a significant interaction between sustained attention in infancy and BI, where highly reactive infants with low sustained attention were more likely to display higher levels of social discomfort at age 14. These findings suggest that infant visual orienting my moderate the relation between temperament and socioemotional competency, perhaps by in part shaping the way that the individual interacts with their social environment through development (Pérez-Edgar et al., 2010b).

By examining patterns of visual orienting at different developmental time points, this literature suggests that emotion regulation throughout the lifespan may be evident in the same early time windows as infant temperament, leveraging aspects of basic visual attention such as looking time and visual disengagement. Additionally, this work also suggests a link between the attentional biases that often characterize anxiety disorders and basic looking behaviors. These associations serve as compelling evidence to examine measures of automatic, stimulus-driven attention to better understand the etiology of anxiety disorders in children of varying temperamental predispositions.

Executive Functioning and Executive Attention

Patterns of visual attention can also be related to, and predictive of, executive functioning. Executive functioning is broadly defined as an individual's control over prepotent responses, including attentional, cognitive, and behavioral processes. Such control allows an individual to flexibly respond to stimuli, even in the face of a competing prepotent response, and supports an individual in accomplishing a goal (Diamond, 2006). A three-factor model divides the broad umbrella term of executive functioning into set shifting, working memory/updating, and inhibition as dissociable components contributing to control of behavior (Miyake et al., 2000).

Higher levels of executive functioning predict conventionally favorable developmental outcomes, such as increased school readiness (Fitzpatrick et al., 2014) and more sophisticated theory of mind (Carlson & Moses, 2001). Impaired executive functioning is related to later diagnoses of externalizing disorders, such as Attention Deficit Hyperactivity Disorder (Barkley, 2007). Deficits in executive functioning are also often found in populations with internalizing disorders, such as depression (Fossati et al., 2002).

Goal-directed behaviors are mediated by brain areas including the anterior cingulate gyrus, basal ganglia, and the prefrontal cortex, labeled as the executive attention network (Posner & Fan, 2008). The executive attention network is later-emerging compared to the orienting attention network (Cuevas & Bell, 2014), with functional connectivity of the associated brain areas emerging on a more protracted course, and continuing to develop through childhood (Rothbart et al., 2011). This protracted neural trajectory is reflected in the later emergence of aspects of top-down visual attention orienting, such as antisaccade capabilities, as well as executive functions. Neural maturation and the development of executive functions follow similar rates of development, both continuing well into adolescence (Amso & Scerif, 2015).

It is not mere coincidence that higher-order visual orienting and executive functioning mirror each other in development - visual attention helps individuals manage and process stimuli in the environment, which in turn works in tandem with executive functioning to effectively align behavior towards higher-order goals. Through selective visual attention, relevant stimuli can be distinguished from and prioritized over non-relevant information. While visual attention and executive functioning are often considered separately, these relations suggest that more advanced and efficient visual orienting may lend to higher levels of executive functioning (Amso & Scerif, 2015).

Associations Between Orienting Attention and Executive Attention

The orienting network and the executive network have significantly overlapping functional connectivity early in development (Cuevas & Bell, 2014). Functional connections may change over time, eventually differentiating these networks on a neural level (Rothbart et al., 2011). However, despite the neural differentiation of these networks, they remain functionally cooperative over development, often operating in tandem to ensure success during goal-directed activities (Rothbart et al., 2011). The development of the executive network and its differentiation from the orienting network represents a shift from reactive behavior to behavior that is more "purposefully" regulatory in nature (Rothbart et al., 2011). This increasing control of behavior allows a child to more effectively modulate their affect using attention processes. Furthermore, individual differences in the orienting attention network may relate to general regulatory abilities and in turn predict differences in executive functioning. The reviewed literature proposes that early individual differences in the orienting attention network impact the later development and functioning of the executive attention network. Therefore, variations in the two networks may interact to shape socioemotional trajectories.

In a longitudinal study, Cuevas and Bell (2014) measured infant looking patterns at 5 months of age by measuring looking time to a puppet. Infants were categorized as "short lookers" or "long lookers" based on their median looking time to the puppet over 4 trials. The same infants were tested on age-appropriate executive function paradigms subsequently at 24, 36, and 48 months. Composite scores were compiled for each time point for the tasks administered. Broadly, children categorized as short-looking infants had significantly higher executive functioning composite scores at all time points compared to those labeled as long-looking infants. This is the first and only study to explicitly examine a link between early orienting attention network functioning and later executive functions (Cuevas & Bell, 2014). This research, albeit limited, supports a longitudinal association between early orienting attention and later-emerging executive attention (Cuevas & Bell, 2014). Thus, executive functioning is presented as a candidate construct to further examine the mechanisms associated with the maintenance of attention biases, specifically attention biases to threat that characterize both BI and anxiety disorders.

From infancy, a child with increased likelihood of BI may demonstrate atypical orienting to environmental stimuli, reflecting early differences in the orienting attention network as a function of temperament (Rothbart et al., 2011). These differences in the orienting attention network may, over the course of early childhood development, lead to differences in the functioning of the executive attention network as well. These differences, in turn, impact how the executive attention network modulates the orienting attention network. Thus, interactions between attention to threat and executive functioning may lead to a distinct pattern of socioemotional functioning when examined within the context of BI (Morales et al., 2016). Our predictions for these idiosyncratic patterns can build on different theoretical models that have sought to explain the relations between orienting attention and executive attention, and specifically how they may operate together in the context of anxiety.

Theoretical Perspectives on the Interplay Between Temperament, Psychopathology, Orienting Attention, and Executive Attention

The Dual Processing Perspective and the Attentional Control Theory are two different theoretical perspectives that postulate the way in which orienting attention and executive attention may interact, specifically in the context of anxiety risk factors and disorders. These approaches agree that these attentional processes are closely interrelated, but differ in the way in which they see anxiety relating to executive attention as well as how differences in executive attention may relate to maladaptive behaviors. These disparate views provide two testable hypotheses on whether higher executive function performance is adaptive for all children, especially in the scope of socioemotional development.

The Dual Processing Perspective. Henderson, Pine, and Fox (2015) detail the Dual Processing Perspective, which is based on the idea that BI children will implement attention orienting, such as attention biases to threat, in a more frequent and non-discriminant manor compared to non-BI peers. This lack of specificity in orienting also lacks efficiency, as the child may allocate cognitive resources to stimuli that do not actually pose a threat. This indiscriminate focus on threat in turn yields the hypervigilance and reticence that in part characterizes the BI temperamental profile. For example, if a BI child enters a room of unfamiliar peers, they may inappropriately enter a vigilant attentional state and exhibit difficulty in comfortably engaging with the other children. Such hypervigilance may present as freezing or remaining on the periphery of the scene (Henderson et al., 2015; Henderson & Wilson, 2017).

In response to this disproportionate allocation of automatic attention to threat, controlled processes like executive attention may then be called upon in equal magnitude, like a positive feedback loop, in attempt to help the individual navigate away from this stimulus. These high levels of executive attention may not be immediately apparent in behavioral data for these children, but are often evident in metrics of neural effort and efficiency (Henderson et al., 2015; Henderson & Wilson, 2017) such as electroencephalography (EEG) event-related potentials (ERPs; Henderson et al., 2015;

Henderson & Wilson, 2017; Lahat et al., 2014; Lamm et al., 2014) and functional magnetic resonance imaging (fMRI; Fu et al., 2017).

Examining types of executive functions specifically, attention shifting ability may impact how readily BI children can orient attention elsewhere after a threatening stimulus, increasing the ease of toggling between automatic and controlled processes, and helping an individual better maintain a balance between these two states. However, increased levels of inhibitory control may actually increase attention allocation to threat in a BI child by supporting behavioral rigidity, making it more difficult for a child to switch between automatic and controlled processes and thus working in the opposite direction of attention shifting. Therefore, inefficiency in shifting from a state of automatic processing to a state of controlled processing, which may stem from high levels of inhibitory control and/or low levels of attention shifting, may in turn contribute to the development of anxious symptomology. If an individual has difficulty in transitioning from automatic to controlled processing, this may potentiate attention biases to threatening stimuli and prolong hypervigilance. This is particularly maladaptive when the perceived threat is not a direct danger to the individual (Henderson et al., 2015; Henderson & Wilson, 2017).

Overall, the Dual Processing Perspective broadly suggests that heightened automatic processing, as sometimes found in BI children, elicits higher levels of controlled processing. However, higher levels of controlled processing, specifically inhibitory control, do not universally predict lower levels of anxiety (Henderson et al., 2015; Henderson & Wilson, 2017). This idea is inconsistent with previous and conventional conceptualizations of executive functioning, but is supported through empirical literature. Carlson and Wang (2007) found a quadratic relation between inhibitory control and emotion regulation, a risk factor for anxiety disorders (Amstadter, 2008; Suveg & Zeman, 2004), such that higher levels of inhibitory control did not universally predict higher levels of emotion regulation. In a sample of preschool children, performance on a battery of both inhibitory control and emotion regulation tasks were significantly correlated, but nonlinearly. Medium levels of inhibitory control predicted the highest level of emotion regulation, with the highest levels of inhibitory control predicting lower emotion regulation ability (Carlson & Wang, 2007). This nonlinear relation between inhibitory control and emotion regulation suggests that inhibitory control is perhaps adaptive to a certain threshold, but at the extremes of both high and low, inhibitory control can be disadvantageous.

Thorell, Bohlin, and Rydell (2004) examined two different processes that share the label of inhibition: inhibition in unfamiliar situations and executive inhibition. They defined inhibition to the unfamiliar as withdrawal from novelty, the common operationalization of temperamental behavioral inhibition. Executive inhibition was defined as distinct from behavioral inhibition, reflecting instead a composite of inhibiting prepotent responses, stopping ongoing responses, and interference control. In this paper, executive inhibition closely mirrors operational definitions of inhibitory control. The authors suggested that inhibition to the unfamiliar and executive inhibition are mediated by overlapping cognitive systems, although they may present orthogonally. Thorell and colleagues (2004) found that both low executive inhibition coupled with low inhibition to the unfamiliar and low executive inhibition coupled with medium inhibition to the unfamiliar predicted hyperactivity. In contrast, high levels of both executive inhibition and inhibition to the unfamiliar predicted low social initiative as well as higher social anxiety. High inhibition to the unfamiliar may be a protective factor in the development of hyperactivity, but it is a risk factor for anxiety when paired with high levels of executive inhibition (Thorell et al., 2004)

Research examining shyness, which is associated with anxiety disorders (Van Ameringen et al., 1998), has also shown that high levels of executive function processes are not necessarily advantageous. For example, Eggum-Wilkens and colleagues (2016) found that higher levels of inhibitory control predicted higher levels of shyness longitudinally, while higher levels of attention shifting predicted lower levels of shyness in the same sample. Here, a positive relation between inhibitory control and shyness, but a negative relation between attention shifting and shyness, demonstrates the merit of differentiating between different forms of executive functioning/controlled processing, especially in examining relations to behaviors associated with anxiety. Where higher levels of attention shifting may be protective for an individual, higher levels of inhibitory control may not predict adaptive outcomes (Eggum-Wilkens et al., 2016)

Similarly, White, McDermott, Degnan, Henderson, and Fox (2011) examined both inhibitory control and attention shifting in BI children. They found that children with high levels of attention shifting were at a decreased risk for anxiety problems, and conversely children with high levels of inhibitory control were at an increased risk for anxiety problems. Attention shifting moderated the relation between BI and anxiety at trend level, and inhibitory control significantly moderated the relation between BI and anxiety symptoms. The authors proposed that the potentiating effects of inhibitory control in BI children could be associated with a lack of adaptability in one's behavior across changing contexts. High levels of inhibitory control may contribute to inflexible and rigid behaviors, especially in emotional, social, or threat-related situations, and thus increased anxiety symptomology. Increased levels of attention shifting may yield higher levels of behavioral flexibility and thus help to ameliorate these temperamental or behavioral predispositions for anxiety (White et al., 2011).

Work with the Dual Processing Model suggests that that increased levels of attention shifting may aid in reducing the frequency/duration of attention allocation to potential threat. However, it also asserts that high levels of inhibitory control can act in a deleterious fashion for BI children, such that high inhibition prolongs the frequency or duration of attention to threat. Maximizing the amount of time that an individual is attending to a perceived threat and in a hypervigilant state is far from ideal and relates to anxious symptomology, thus behaviors that help to break these biases and minimize non-goal directed, non-restful time when there is indeed no threat would be the most adaptive.

Attentional Control Theory. In contrast to Dual Processing Perspective, Attentional Control Theory (Eysenck et al., 2007) proposes that anxiety disrupts the balance between executive attention, which is goal-directed and top-down in nature, and the more stimulus-driven, bottom-up, orienting attention. This disruption is thought to yield reduced attentional control in anxious individuals. The authors postulate that specifically in anxious populations, orienting attention is increased at the expense of executive attention. Because anxious individuals devote increased attentional resources to stimulus-driven attention, like biased attention to threat, individuals therefore have less resources to devote to goal-directed processes, like an executive functioning laboratory task. Their attention may be easily captured by non-task relevant external distractors such as those in a computer paradigm, or even internal distractors such as worry, and attention is pulled away from the goal at hand.

Attentional Control Theory also emphasizes a distinction between task performance and task efficiency, similar to the Dual Processing Perspective, where task performance refers to measures such as accuracy but efficiency describes measures such as reaction time and effort expended to complete a task. Theorists suggest that this trade-off between orienting attention and executive attention, where orienting attention is prioritized in anxious individuals, is evident most strongly in metrics of task efficiency but less so in task accuracy. For example, anxious participants may take longer to respond on tasks in a myriad of domains, ranging from working memory to spatial reasoning. Moreover, when asked to self-report the effort that they exerted on a task, anxious participants will report significantly higher effort as compared to non-anxious controls but still exhibit comparable performance (Eysenck et al., 2007).

These group-related deficits may not always be perceptible on more simplistic laboratory assessments, but become more apparent as task difficulty increases. Deficits may also become increasingly apparent as distractors increase in saliency to the individual, such as in the case of threatening distractors, which would capture a larger proportion of stimulus-directed attention (Eysenck et al., 2007).

The Attentional Control Theory suggests that, of the abilities governed by the central executive, the concept of attentional control is closely linked to both inhibition and set shifting. Eysenck and colleagues (2007) suggest that in anxious populations, efficiency on a task involving any combination of inhibition or set shifting will likely suffer. In anxious individuals, there is a baseline surplus of resources allocated to stimulus-directed attention and therefore a paucity of resources available for goal-directed attention. Therefore, completing a task requiring goal-directed attention, like inhibition and/or set shifting, may be much more effortful for an anxious individual and will take them more time, but with less apparent deficits in behavioral measures of accuracy (Eysenck et al., 2007).

Toren and colleagues (2000) empirically supported the Attentional Control Theory in their study examining children, ranging from 6-18 years of age, with separation anxiety disorder and overanxious disorder as they performed the Wisconsin Card Sorting test. They found that children with either anxiety diagnosis scored significantly worse on both total errors and perseverative responses as compared to the control group. These results suggested early-appearing deficits in attention shifting in anxious populations. Work by Lengua (2003) suggested an inverse relation between inhibitory control and anxiety disorders in a group of 3rd-5th graders. Higher levels of inhibitory control predicted, both concurrently and longitudinally, lower reported internalizing problems. They also saw that higher levels of inhibitory control predicted lower externalizing problems as well as higher levels of social competence (Lengua, 2003). Similarly, Kooijmans, Scheres, and Oosterlaan (2000) suggested evidence of a negative relation between inhibitory control and internalizing behaviors, as well as between inhibitory control and externalizing behaviors (Kooijmans et al., 2000).

Wolfe and Bell (2014) also replicated differences in neural effort during executive function tasks in a sample of shy and non-shy children. Shyness and BI share features such as wariness to novel social stimuli (Wolfe & Bell, 2014). Social shyness is also associated with anxiety disorders (Van Ameringen et al., 1998). In this study (Wolfe &

Bell, 2014), children completed an executive functioning battery in the presence of a stranger, including two Stroop-like tasks during which EEG data was recorded. Executive functioning composite scores were generated. Baseline EEG was also collected prior to task onset.

Regardless of shyness classification, children with high executive functioning composite scores displayed an increase in medial frontal EEG power from baseline to task. Amongst those with low executive functioning composite scores, shy children also displayed an increase in medial frontal EEG power, but non-shy children did not. Looking at medial parietal sites, shy children displayed an increase in medial parietal EEG power regardless of performance on the executive functioning tasks. For non-shy children, increases in EEG were coupled with increases in performance, providing a functional link absent in the shy children.

Overall, children who had strong executive functioning skills displayed a task-related increase in frontal EEG power, as did shy children with lower executive functioning skills, suggesting that shy children with low executive functioning exerted similar neural energy to their high-performing counterparts. However, this higher effort was not evident in their performance (Wolfe & Bell, 2014). The pattern of increased activation, without associated improvement in performance, is evidence of “cognitive busyness” – where shy children may be balancing other task-irrelevant intrusive thoughts with the demands of an executive functioning task, thus yielding increased brain activation at frontal and parietal sites, possibly to the detriment of their task performance (Wolfe & Bell, 2014).

These differences in executive functioning supporting the Attentional Control Theory are also seen in comparing anxious versus non-anxious adult populations, where on controlled processing tasks anxious adults have shown longer latencies to respond (Ansari & Derakshan, 2011; Bar-Haim et al., 2005; Basten et al., 2011), lower accuracy rates (Basten et al., 2011), and differences in the cognitive resources expended to complete the task as measured by EEG/ERP (Bar-Haim et al., 2005) as well as fMRI (Basten et al., 2011).

The Attentional Control Theory, like the Dual Processing Perspective, emphasizes the importance of looking beyond simple accuracy measures in a task, and utilizing both behavioral and neural metrics of efficiency and effort in characterizing the "success" of anxious and non-anxious groups in completing assessments of executive functioning. Where group differences may not always become immediately apparent in a raw accuracy metric, they may be manifest in seeing how quickly these tasks can be completed accurately, and furthermore what cognitive resources must be expended to perform at this level. High levels of automatic processing often evident in anxiety disorders and BI may relate to a decrement in levels of executive attention, suggesting an inverse relation between EF and maladaptive behaviors.

In comparing both the Dual Processing Perspective and the Attentional Control Theory, both theories concur that orienting and executive attention are indeed interrelated processes, operating in tandem rather than independently. They both suggest that either internalizing disorders or risk factors thereof are associated with higher levels of orienting attention. The theories also both discuss the value of measuring effort/efficiency in addition to accuracy measures, as this metric may better characterize differences in executive attention/executive functions as compared to accuracy alone. Additionally, they agree that attention shifting, a sub-behavior encompassed by EF, may operate adaptively in all populations by assisting in flexible switching between states of orienting attention and executive attention. Where these theories primarily diverge is in their view of inhibitory control and the way in which levels of this specific type of executive attention may interact with individual differences in orienting attention.

The Dual Processing Perspective suggests that elevated levels of orientating attention, such as that found in BI children, calls upon high executive attention to try and navigate around these attentional biases. However, high inhibitory control may pave the way for rigidity in behavior and make it difficult for an individual to alternate between orienting attention and other states of executive attention. Difficulty in navigating these attentional biases may in turn cause the child to remain in a hypervigilant state and thus put them at higher risk for internalizing and anxious behaviors.

In contrast, the Attentional Control Theory proposes that high orienting attention may be at the detriment of executive attention, such that low inhibitory control is an additional risk factor for internalizing disorders but increased levels are protective. Implementing innovative, ecologically valid methodology may be the key to elucidating which mechanism best characterizes paths of risk and resilience for BI children, to better understand how orienting and executive attention may unfold and interact in the "real-world."

Considerations in Measurement

Naturalistic measures of visual attention and executive functioning. The field of psychology has a long-standing history of utilizing highly standardized tasks in the measurement of constructs including visual attention and executive functioning. Stationary eye tracking is a tool frequently used to allow for quantitative measurements of visual attention to objects presented on a computer screen. This measure allows for the examination of the multiple processes that may lead up to the motor responses elicited by a paradigm. In many protocols, a button press is often the ultimate outcome of a trial, and the data capture accuracy and/or reaction time of the response. Eye-gaze measures may provide insights into the computational processes that lead to the motor response. May and colleagues (1990) suggest that eye movements may serve as a metric of mental workload, such that the extent of saccades becomes more restricted as demands increase, and that saccadic range may also relate to task performance (May et al., 1990). For example, in a naturalistic driving experiment the number and pattern of visual fixations distinguished between novice and experienced drivers, reflecting differences in workload as a function of competency (Underwood et al., 2003).

Moreover, eye tracking can even remove the necessity of a button response in populations where a button press may not be developmentally possible, such as infants completing the dot probe task (Pérez-Edgar et al., 2017). Whereas the traditional dot probe paradigm requires a button press to indicate that a participant has attended to the probe stimulus, this study used eye tracking to quantify when the infant made the saccade to/fixated upon the probe. Thus, eye tracking minimizes confounds of age or ability in assessments of both orienting and executive attention (Burris et al., in press). Overall, stationary eye tracking has the ability to provide a richer measurement of human attention and behavior in a wider range of developmental stages and abilities.

Highly controlled computer tasks offer a large amount of experimental control and precision. However, they may lack ecological validity. Task setup is often limited by conventionally bulky technology such as eye trackers, so a participant usually sits in a chair at a desk to play a "game" assessing a psychological construct. However, in the "real world," cognitive operations unfold in a context much more complex than a dark room with a computer screen, with a myriad of competing stimuli and motivations that may influence behavior just as much as the task itself (Ladouce et al., 2017). Much of what is known about human behavior and its neural correlates is specific to an operationalization in its most sterile and simplistic form.

Real-life and real-time cognition unfolds in an environment that is not only complex (Ladouce et al., 2017), but also emotionally-charged. Where many computer tasks not directly measuring social behavior may be devoid of social stimuli, the "real world" is often inherently social in nature, with these social factors also influencing task performance. Assessments of executive functioning devoid of social components also may not capture a translatable assessment of executive functioning, especially in populations with potentially altered socioemotional trajectories. Using social stimuli, and specifically faces that are dynamic and mutually responsive, in cognitive paradigms may be key in expanding the ecological validity of psychological science (Risko et al., 2016).

Emerging technologies have made mobile eye tracking a feasible method to acquire metrics similar to stationary eye tracking in more translatable, true-to-life paradigms, allowing for the quantitative measurement of visual attention patterns like attention biases in naturalistic settings (Fu & Pérez-Edgar, 2019). However, implementing more ecologically valid paradigms necessitates the relinquishing of some degree of experimental control, and is far from free of methodological shortcomings (Ladouce et al., 2017). Ambulatory data collection may introduce the challenges of increased noise in the data. In addition, it may be difficult to ensure that all participants are providing comparable data for analysis (Ladouce et al., 2017). A solution to this possible limitation is utilizing "lab-controlled" naturalistic paradigms, where the child is asked to do a seemingly ordinary task that they may do in school or at home, like play a game, while the experimenter they interact with is held to a standardized set of behaviors. This practice ensures that each child receives a comparable set of stimuli, while they are still allowed to act and move free of many traditional laboratory constraints.

The Current Study

Our testing and analysis will focus on measuring inhibitory control, examining the way that inhibitory control may exacerbate or ameliorate risk of maladaptation in BI children, as this is the primary point of contention between the Dual Processing Perspective and Attentional Control Theory.

The Tower of Patience is a task that has been widely used as an assessment of inhibitory control in children. The child and a familiar experimenter take turns either building a tower with blocks (Buss et al., 2014; Dyson et al., 2012; Kochanska et al., 1996; Smith et al., 2013; von Suchodoletz et al., 2009) or withdrawing blocks from a Jenga-style tower (Durbin et al., 2007; Ruf et al., 2008). With each turn, the experimenter follows a schedule of increasingly lengthened delays to take their turn, making the child wait longer to continue game play. Behavioral measures extracted focus on different violations of the turn-taking rule, such as the child skipping the experimenter's turn and continuing to choose their own block, where less adherence to the turn-taking rule is associated with lower inhibitory control (Buss et al., 2014; Kochanska et al., 1996; Smith et al., 2013).

Unlike some other commonly used tasks to assess inhibitory control, like Go No-Go computer tasks, this "game" is occurring in a playroom context which may be more familiar to circumstances they would encounter in school or at home. With the increased ecological validity implicated in this task, mobile eye tracking allows researchers to collect information on visual attention patterns that may precede an overt response in a naturalistic scene, like violating the "turn taking" rule. The ecological validity afforded by mobile eye tracking also allows us to characterize visual attention patterns associated with inhibitory control in BI and non-BI children in more naturalistic situations and environments such as the Tower of Patience task. These data provide greater generalizability and translation when examining how BI children visually process their surroundings, the way in which visual attention may gate behavior, and what behaviors may predict higher levels of anxiety.

Anxiety and internalizing behaviors. Thus far, anxiety has been a main focus of this review. Relations between temperament and executive functions have been guided by both adult and child anxiety literature, with anxiety disorders considered as a negative downstream consequence of the interaction of these risk factors. While anxiety disorders are seen in children as young as preschool-age (Franz et al., 2013), onset can be as late as adolescence or adulthood depending of the type of anxiety disorder (Beesdo et al., 2009). The sample for the current study (detailed further below) is both young and healthy, a community sample of children 5-7 years of age. Therefore, there is a low likelihood that many children in this sample, albeit at some level of risk for anxiety, will display symptoms at or near a clinical threshold at this time point.

Anxiety falls under the broader classification of internalizing problems. The Child Behavioral Checklist (CBCL; Achenback & Edelbrock, 1983) defines internalizing problems by a composite of items assessing emotional reactivity, anxious/depressed behaviors, somatic complaints, and withdrawn behaviors. This may include parental reports of the child frequently sulking, reporting hurt feelings, complaining of aches and pains without a medical cause, and avoiding eye contact with others, respectively, to name just a few items included in the scale. In the context of this study, measuring internalizing symptoms, rather than only anxious symptomology, offers greater analytic variability, and developmental match, within the sample.

Aims. The current study addressed the following two research questions:

1. Do behavioral violations of rules in the Tower of Patience game, reflecting a child's inhibitory control, moderate the relation between BI and internalizing symptoms in a sample of kindergarteners?

2. Do patterns of visual attention during a task targeting inhibitory control moderate the relation between BI and internalizing symptoms in the same sample of kindergarteners?

Hypotheses. Our hypotheses for each identified aim are as follows:

1. If the Dual Processing Perspective is reflected in these data, we would expect increased inhibitory control, operationalized by fewer rule violations in the Tower of Patience task, to positively moderate the relation between BI and internalizing symptoms. In this scenario, BI children with greater inhibitory control would show more

internalizing symptoms and BI children with lower inhibitory control would show comparatively fewer internalizing symptoms. If the Attentional Control Theory is supported by the data, we would expect increased inhibitory control to negatively relate to report of internalizing symptoms, regardless of level of BI. Both BI and non-BI children with greater inhibitory control would show fewer internalizing symptoms and children with lower inhibitory control would show more internalizing symptoms.

2. Because of the novelty of mobile eye tracking data, and thus a lack of prior work, it is difficult to hypothesize how patterns of naturalistic visual attention may moderate the relation between BI and internalizing symptoms. However, we predict that gaze to game-relevant and game-irrelevant areas of interest (AOIs) will significantly map onto to the child's behavior during the task, suggesting that visual attention may relate to regulation the child may deploy in response to task demands. Within the scope of this project we did not empirically test and therefore cannot infer which gaze patterns are regulatory and which are not. However, the Dual Processing Perspective suggests that high behavioral regulation in the form of high inhibitory control may act as a risk factor for maladaptive socioemotional outcomes specifically in BI children, but acts adaptively in non-BI children. On the other hand, the Attentional Control Theory does not make a distinction between BI and non-BI children, suggesting overall that inhibitory control is negatively related to maladaptive behaviors like anxiety. While we are unable to directly assess whether patterns of gaze associated with high regulation moderate the relation between BI and internalizing symptoms, we can test whether gaze patterns elicited by an inhibitory control task are related to internalizing symptoms, and whether this relation varies as a function of BI. Therefore, if the Dual Processing Perspective is supported in

these data, there will be a significant interaction between BI and gaze patterns in relation to internalizing symptoms. On the other hand, if the Attentional Control Theory is supported, this interaction will not be significant, and rather the relation between gaze and internalizing symptoms will be the same for both BI and non-BI children. We recognize, however, that a small sample size (detailed below) may limit power to detect these interactions in the data set, which may work against these data supporting the Dual Processing Perspective.

Chapter 2

Methods

Sample

Participants were 37 children ranging from 5- to 7- years of age (M = 6.19 years, SD = 0.58, 48.6% female) identifying as White (83.8% n = 31), Asian (8.1%, n = 3), African American (2.7%, n = 1), Hispanic (2.7%, n = 1), and other (2.7%, n = 1), reflective of the demographics of the surrounding community. Participants were recruited from a college town in central Pennsylvania and oversampled for high levels of BI (12 BI, 32.4% of the sample). Families were contacted using a database of families who had previously interest in participating in research studies, as well as by way of community outreach opportunities and word-of-mouth. Participants were not enrolled if they identified as non-English speakers, had gross developmental delays, or if the child had a history of severe neurological or medical illnesses. All study procedures were approved by the Institutional Review Board and the Pennsylvania State University. All parents and children completed written consent/assent prior to commencing the visit and they were monetarily compensated for their time.

Prior to scheduling a visit to the lab, 163 children were screened for levels of BI via the Behavioral Inhibition Questionnaire (BIQ; Bishop et al., 2003). As in previous work (Broeren & Muris, 2009; Fu et al., 2017; Thai et al., 2016) children were recruited as a BI participant if their total BIQ score is greater than or equal to 119, and/or if their social novelty subscale score is greater than or equal to 60. Of the 163 participants who were screened, 39 individuals (23.9%) met the criteria for classification as BI.

In the larger study, 89 children were brought in for a visit to the lab. Of these 89, 25 children (28.1%) met criteria for BI classification. The mean age of the sample was 6.06 years (SD = 0.60), with 44 females. The sample predominantly identified as White (n = 77, 86.5%), similarly matching the demographics of the region. Data were excluded from the final analysis for the following reasons: the first 23 participants were used for piloting the protocol and were thus not included in the analysis, 24 participants were excluded for poor calibration and/or tracking, one participant was excluded for unintelligible audio, one child was excluded for missing room video footage, two participants were excluded for corrupted files, one child asked to remove their eye tracker, three children asked to discontinue testing before the episode was attempted, and finally one child was randomly selected and excluded for being the twin of another participant. In selecting participants for use in the final analysis, we were conservative in setting a threshold for data quality so as to minimize noise in the data. There were no significant differences in BI or internalizing symptoms between the included and excluded participants, except that the participants excluded ($M_{age} = 5.95$) were significantly younger than the participants included (M_{age} = 6.20) in the analysis ($t = -2.04$, $p < .05$).

Procedure

Prior to arrival to the laboratory, parents completed a series of online questionnaires about themselves and their children. Of relevance in this analysis is survey report of both child temperament and child internalizing symptoms, as reported by the parent. BI was measured via the Behavioral Inhibition Questionnaire (BIQ; Bishop et al., 2003). The BIQ is comprised of 30 questions that assess the parent's report of the child's response to novelty. The BIQ utilizes a likert scale ranging from 1 ("Hardly Ever") to 7 ("Almost Always") as a response to each question. While the BIQ was used to initially recruit participants categorically, BI was assessed as a continuous variable in these analyses, where children with a higher BIQ score displayed higher levels of BI behaviors. The mean BIQ score of the sample was 94.59 (SD = 28.24)

Additionally, the internalizing subscale of the CBCL (Achenback & Edelbrock, 1983) was used to quantify internalizing symptoms in participants. The CBCL includes a list of possible childhood behaviors, where parents are asked to endorse whether this behavior is "not true" (0), "somewhat or sometimes true" (1), or "very true or often true" (2) for their child. The score of this subscale was also assessed as a continuous variable, where higher values on this subscale reflected a higher count of reported internalizing behaviors. The mean count of internalizing behaviors in this sample was 6.16 (SD = 5.45).

Tower of Patience task. The Tower or Patience task was used as a measure of inhibitory control. In this episode, the child is seated at a table and introduced to a Jenga-like game, where they must take turns and takes turns playing with a familiar experimenter. They are told that they will be alternating withdrawing wooden blocks from a vertically stacked tower but avoiding the tower's collapse, and placing each selected block in an adjacent box after every turn. The blocks were three different colors, with each vertical third of the tower colored either blue, yellow, or red. Based upon these colors the child was also introduced to a scoring scheme, where the lower third of blocks in the tower were worth three points if selected, the middle third were worth two points, and the final top third were each worth one point. The children were told that the player with the most points at the end of the game won. With each subsequent turn, the experimenters increasingly delay in choosing a block to remove from the tower. With the increasing delays, some children are unable to inhibit the urge to jump in and take a turn.

While more "naturalistic" than many standardized laboratory measures of EF, the task was controlled in that the experimenter was provided time intervals to adhere to as closely as possible during the game. Of interest were 7 trials with time intervals as follows: trial 1 = no wait period, trial 2 = 10 second wait period, trial 3 = 20 second wait period, trial 4 = 30 second wait period, trial 5 = no wait period, trial 6 = 40 second wait period, trial 7 = 60 second wait period. After the final 60 second wait period, the experimenter would "accidentally" knock down the tower to end game play. This timeline was adhered to relatively closely through testing (Table 1).

Table 1-1. Mean and Standard Deviation of the duration of each task trial in seconds

Trial Number	Mean (seconds)	Standard Deviation (seconds)
Trial 1	4.50	2.21
Trial 2	15.93	4.11
Trial 3	25.53	4.34
Trial 4	38.49	5.07
Trial 5	6.25	3.23
Trial 6	49.41	6.13
Trial 7	63.55	10.56

If the tower accidentally fell over during the progression of trials, the experimenter would re-build the tower, take a turn with no wait period, and then continue with the next specified trial. During each wait period, the experimenter was instructed to keep gaze and behavior ambiguous, so it was not clear to the child what was causing the delay. If the child spoke to the experimenter during the wait period, the experimenter either disregarded the child or provided a brief answer. If the child violated the turn-taking rule, the experimenter would wait until the trial was over to remind the child, "Remember how to play this game. First, I take a block, and then you take a block, then I take one, then you take one. That's how we play this game." Any subsequent violations of turn-taking were left unacknowledged. Four research assistants acted as the primary experimenter in the current sample (all female).

Ambulatory eye tracker. Participants were fitted with a Pupil binocular ambulatory eye tracker for the Tower of Patience game, as well as for other games in the larger study (Pupil Labs; Kassner et al., 2014). These “glasses” include two cameras, each pointing at an eye, in addition to a “scene” camera centered on the space in front of the child to capture their world view. Data were recorded with Pupil Capture v.0.9.12 (Pupil Labs), which was installed on an MSI VR One Backpack PC which allowed the child to move freely through the visit. To enable real-time monitoring of data quality throughout the experiment, the PC was remotely connected to a monitor located in a separate room.

Akin to stationary eye tracking, after the child was outfitted with the glasses and backpack, gaze was calibrated by asking the child to look at 5 distinct targets on a large projection screen. After calibration, children participated in other activities that were included in the larger study, until they were led to the room with the task of interest. Prior to the beginning of each task, gaze was “validated” by asking the child to look at locations that the experimenter pointed to on a bullseye graphic, which was held at a distance matching the distance of AOIs in the task (http://bit.ly/MET_OSF). For this episode, the child looked at a smaller bullseye printed on an 8.5” x 11” sheet of paper, and held at the same location as the experimenter’s face during the upcoming task.

Data Processing

Behavioral Data Processing. A coding scheme was developed to mark the onset and offset of each wait period, as well as quantify frequency and onset/offset of violations of turn-taking as well as the child’s bids to the experimenter to encourage them to take their turn. Behavior was also coded using Datavyu (Datavyu Team, 2014). A combination of the child’s mobile eye tracking footage, a video captured of the scene using a video camera set up behind a two-way mirror, and audio recorded in the room was used to provide the most comprehensive coverage of behavior during the episode. A total of two independent coders completed behavioral coding for the sample, overlapping on 20% of videos to ensure reliability.

A trial onset was defined by when the child's selected block hit the bottom of their box used to store the drawn blocks. The trial offset was marked when the experimenter's selected block hit the bottom of their box, and/or the experimenter verbally told the child, "now it's your turn!" If trials were out of order due to experimenter error or due to the tower falling before the game was complete, the coders adjusted the label of the trial such that it most closely matched the amount of time that the child had to wait, rather than the temporal order of trials originally established in the protocol. Coders agreed on an average of 96.2% (SD = 2.25%) of frames in designating the beginning and ending of each trial.

The child's behavior was also coded for violations of the turn-taking rule, as well as verbal and physical prompts to the experimenter to take their turn. A violation of turn taking was defined as the child removing blocks from the tower before the experimenter had chosen their block. The onset of the violation of turn taking was defined as the child touching the block in the tower, and the offset was defined as the block landing in the bottom of their box.

A verbal prompt was defined as the child encouraging the experimenter to take their turn or commenting on how long they had been waiting. Examples included, "It's your turn" or "Why do you take so long?" Chatter related to the game but not pertaining to the wait time or the experimenter's pending turn (e.g. "I used to play this game at home.") was not coded as a verbal prompt.

A physical prompt was defined as physically directing the experimenter's attention to the tower, which could include pushing a block toward the experimenter, pointing at the tower, or attempting to select but not actually withdrawing a block. Gestures accompanied by vocalizations pertaining to the child's own self planning (e.g. "what if I pick this one?") were not coded as a physical prompt. Overall, coders agreed on an average of 98.87% (SD = 1.09%) of frames denoting the onset, offset, and type of behavior.

Summary variables computed from this behavioral coding included the total number of verbal prompts, physical prompts, and turn skips across all wait periods, as well as the latency to the child's first verbal prompt. In coding the latency, a wait period was scored as the full time as per the protocol if the child made no verbal prompts. If they did make a prompt, the onset of that wait period during which the prompt occurred was subtracted from the onset of the verbal prompt, and rounded to the nearest second. This value and the duration of all previous wait periods were then summed. If the child made no verbal prompts through the episode (N = 13), they were assigned the total value of all wait periods in the protocol, 160 seconds. Of interest in our analyses were the number of both verbal prompts and turn skips, as well as latency to the first verbal prompt.

Eye tracking data processing. In order for gaze to objects in the room can be quantitatively measured, Pupil Player v.0.9.12 (Pupil Labs) was used to superimpose a bullseye atop the child's "world view," reflecting where they were looking in the scene. The bullseye appeared as three concentric circles with crosshairs. The radius of each circle was proportional to the screen resolution (red: 2º; yellow: 5º; green: 8º) (Figure 1).

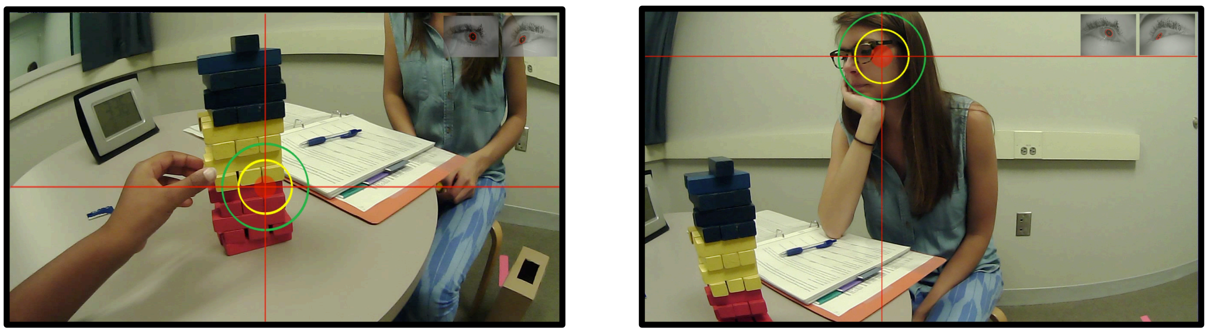

Figure 1-1. Bullseye overlaid on scene view to indicate location of gaze.

Gaze was corrected to the validation target that preceded the episode also using Pupil Player v.0.9.12 (Pupil Labs). As described above, before the task the experimenter cued the child's attention to 5 points along a target held at the same distance as task AOIs. Two trained independent coders examined the validation procedure for each participant to ensure that the indicated points were within the red circle of the gaze bullseye, and that the indicated gaze aligned with where the child was actually looking.

If coders noted that the recorded gaze differed from the cued locations in a systematic fashion (i.e. consistently skewed to the left or to the right), gaze corrections were made using the manual gaze correction plug-in in Pupil Player v.0.9.12 (Pupil Labs). For each participant requiring correction, independent coders used the plugin to adjust the positioning of the concentric circles/bullseye such that the cued points were within the red circle of the bullseye. If corrections for each coder were within 0.03 units of each other on both the x and y axis, the master coder's corrections were used. If the discrepancy between coders' corrections was greater than 0.03 units on either the x or y axis, the two coders conferred to agree upon the best gaze correction for that participant. Following a final correction, the video was exported and synced with synchronous room recordings using Final Cut Pro. Videos were exported at a resolution of 1920x1080 pixels and a framerate of 30 frames per second.

Many stationary eye tracking processing pipelines rely on stimuli and AOIs remaining in a fixed location in 2D space, such as on a computer screen. Mobile eye tracking differs from its traditional stationary counterpart in that the scene is in constant motion and the AOIs are dynamic, either inherently or because their positioning may vary as a function of the viewer's location and head positioning. Thus, more automatized gaze processing pipelines used in handling stationary eye tracking data do not easily extrapolate to mobile eye tracking data. As an alternative to automatic gaze processing, the mobile eye tracking video data were coded frame-by-frame using Datavyu (Datavyu Team, 2014), utilizing methods in published studies (Franchak & Adolph, 2010; Franchak, et al., 2011; Fu et al., 2019; Kretch & Adolph, 2015; Kretch et al., 2014). Videos coded were 30 frames per second, which can be likened to stationary eye tracking collected at 30 hz. Gaze to the following AOIs were coded continuously: the Jenga blocks, the experimenter's head and body, the boxes to store the selected blocks, the child's self, the reflection of the experimenter in a room mirror, and looking elsewhere in the room. The coder also denoted frames that were "indeterminate," in which either a) gaze was outside of the frame of their world view or b) the participant's pupil was not successfully tracked by the eye camera, either resulting in absent crosshairs on the video data therefore making it not possible to mark where the child was looking. A primary coder coded 100% of each video, and a secondary coder coded at least 20% of each video, to ensure reliability. Coders agreed on an average of 96.25% of frames (SD = 2.68%).

As reviewed, ambulatory data collection may be prone to higher levels of noise, such as motion artifacts, which yielded the "indeterminate" frames mentioned above. We created proportions scores for time spent attending to each coded AOI (Jenga blocks, the experimenter's head and body, the boxes to store the selected blocks, the child's self, the reflection of the experimenter in a room mirror, and looking elsewhere in the room). Gaze data was segmented so it only included gaze during the wait periods of each trial. Proportion scores to each AOI were generated with the denominator as the amount of tracked time during the wait trials, subtracting the amount of "indeterminate" time from the total time across wait trials, so proportions were not biased by varying degrees of data quality and accounted for differences in missing data across participants.

The reviewed literature suggests that visual attention can be used as a regulatory mechanism (Rothbart et al., 2011) as well as a way to direct behavior toward a goal (Amso & Scerif, 2015). Thus, we a priori selected AOIs to focus on in our analyses that were either related to the task at hand (the experimenter, the Jenga tower) or AOIs that were unrelated to the task and any goals (the surrounding room).

Chapter 3

Results

Behavioral Data

Descriptive statistics for the computed behavioral measures suggest a non-normal distribution of values across participants as well as notable ceiling/floor effects, but a wide range in both latency and frequency of behaviors (Table 2, Figures 2-4). Spearman's correlations found that BI level was significantly positively associated with report of internalizing behaviors, consistent with previous literature ($b = 0.57$, $p < .001$). There was a significant negative relation between BI and number of verbal prompts ($b = -0.38$, $p = .02$) such that children with higher reported BI made significantly fewer verbal prompts during the wait periods of the task which were most directly taxing inhibitory control. There was also a significant positive association between level of BI and latency to the child's first verbal prompt ($b = 0.40$, $p = .02$), where children with higher BI took longer to make their first verbal prompt. There were no significant associations between number of skipped turns and BI. Additionally, neither report of internalizing symptoms nor age or gender were significantly correlated with any behavioral measures, and there were no significant correlations between any of the behavioral measures. These correlations can be seen in Table 3.

Table 2-1. Descriptive statistics for behavioral data

	Mean	SD	Range	
			Min.	Max.
Total number of turn skips	0.49	1.48	0.00	6.00
Total number of verbal prompts	2.97	3.82	0.00	14.00
Latency to first verbal prompt (seconds)	84.51	69.96	2.00	160.00

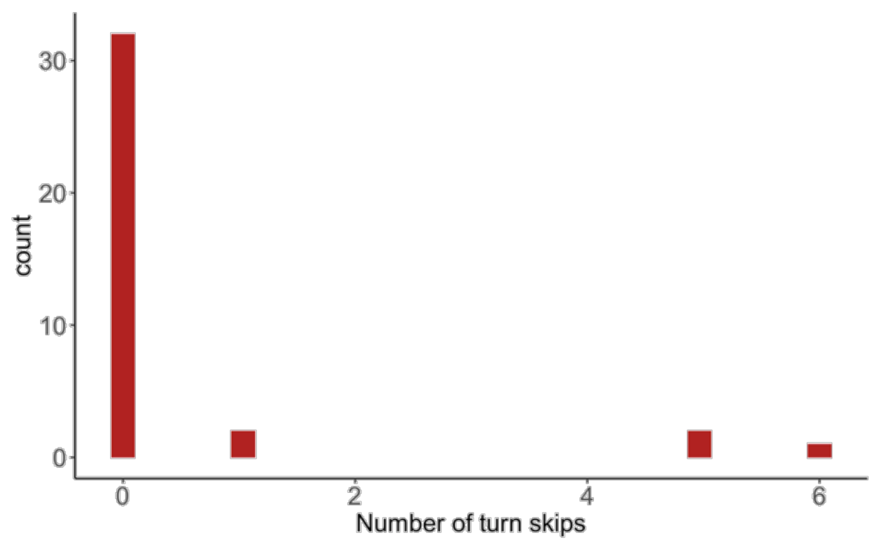

Figure 2-1. Histogram depicting distribution of number of skipped turns in the sample.

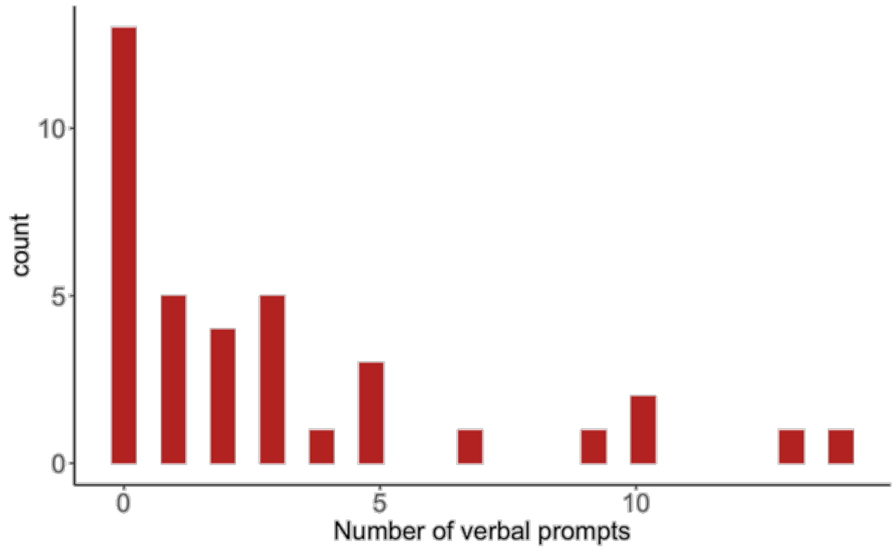

Figure 3-1. Histogram depicting distribution of number of verbal prompts in the sample.

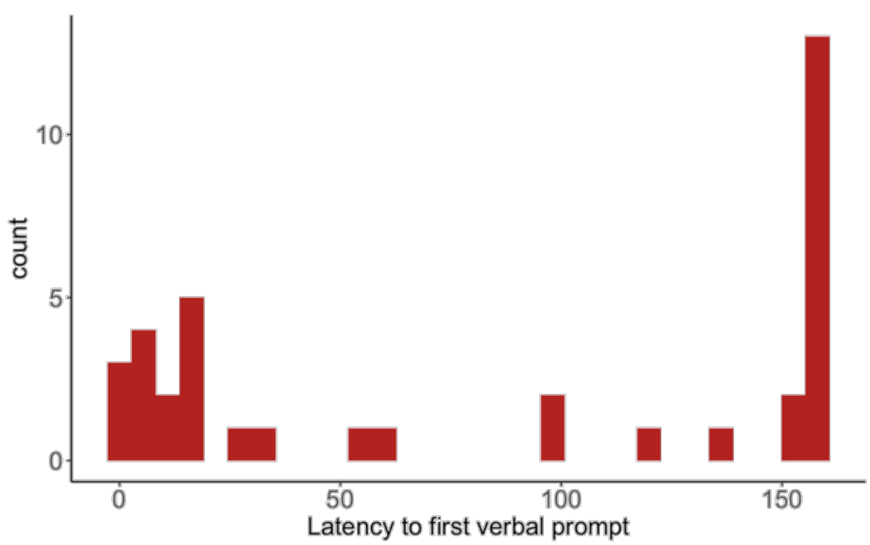

Figure 4-1. Histogram depicting distribution of latency to first verbal prompt in the sample.

Table 3-1. Spearman's correlation table showing interrelations between demographic and behavioral variables of interest.

	1.	2.	3.	4.	5.	6.
1. Sex	--					
2. Age	-0.19	--				
3. BIQ total score	0.19	0.03	--			
4. Internalizing subscale – CBCL	0.08	-0.19	0.57***	--		
5. Number of skipped turns	-0.06	-0.09	-0.23	0.03	--	
6. Number of verbal prompts	-0.02	-0.23	-0.38*	-0.07	0.12	--
7. Latency of first verbal prompt	-0.04	0.08	0.40*	0.11	-0.18	-0.84***

As reviewed, both the Attentional Control Theory and the Dual Processing Perspective suggest that levels of inhibitory control may negatively and positively, respectively, moderate the relation between BI and internalizing symptoms. We tested this model with count of verbal prompts, count of turn skips, and latency of first verbal prompt each as moderators. No interactions were significant, however each model had a significant positive main effect of BI.

Mobile Eye Tracking Data

To assess data quality tracking ratios were computed for each participant, dividing the amount of tracked time across wait periods by the amount of total time across wait periods. On average, 71.3% of participants' gaze was tracked (SD = 0.14). Additionally, descriptive statistics for mobile eye tracking measures suggest a more normal distribution of measures across participants, but also significant variability (Table 4, Figures 5-7).

Table 4-1. Descriptive statistics for mobile eye tracking data

			Range	
	Mean	SD	Min.	Max.
Proportion of gaze to Jenga blocks	0.42	0.17	0.11	0.77
Proportion of gaze to experimenter	0.20	0.13	0.00	0.51
Proportion of gaze to room	0.24	0.12	0.08	0.62

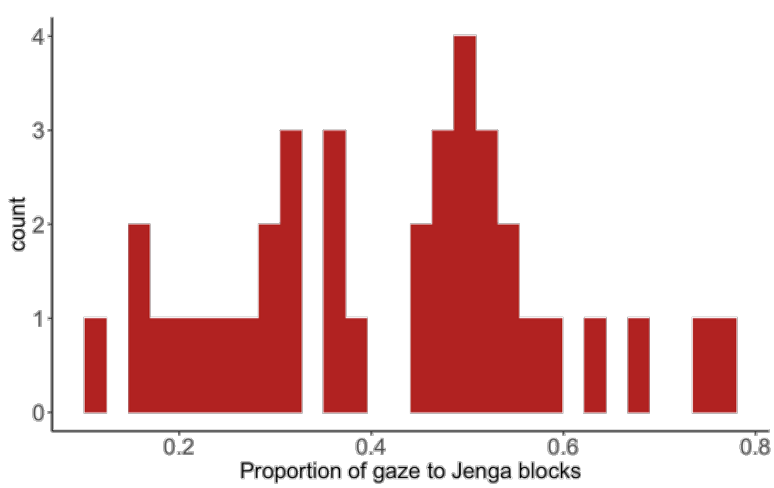

Figure 5-1. Histogram depicting distribution of proportion of gaze to Jenga blocks in the sample

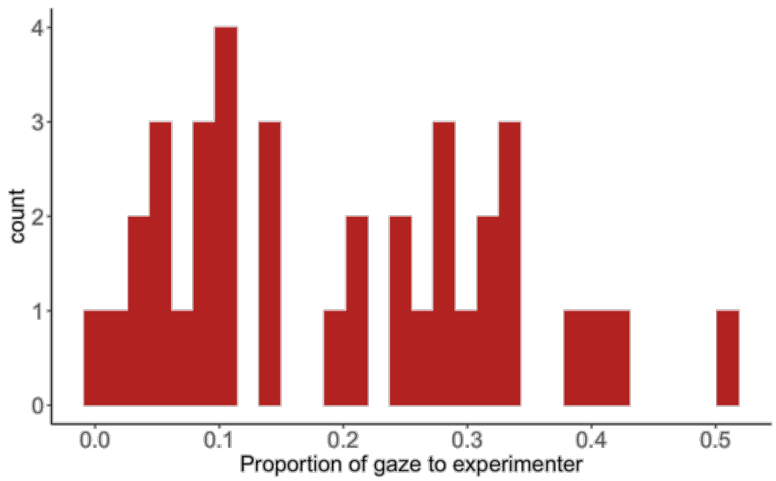

Figure 6-1. Histogram depicting distribution of proportion of gaze to the experimenter in the sample

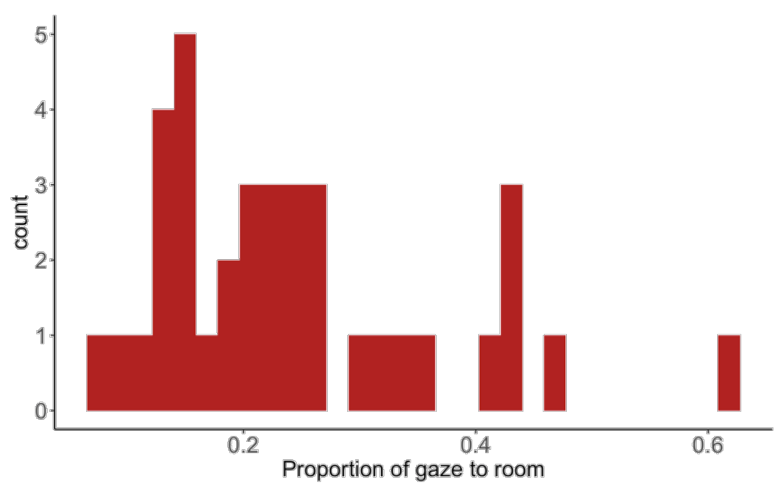

Figure 7-1. Histogram depicting distribution of proportion of gaze to the room in the sample

Spearman's correlations were used to preliminarily assess interrelations between visual attention and behavior during the episode. Of note, we found that proportion of gaze to the room during the wait periods was negatively related to the latency to the child's first verbal prompt at trend level, $b = -0.32$, $p = .06$, that is children who attended to the room waited less time to verbally prompt the experimenter (Table 5).

Additionally, proportion of gaze to the Jenga blocks was positively related to the latency to the first verbal prompt, $b = 0.35$, $p < .05$, and was inversely related to the number of verbal prompts that the child made during the wait periods, $b = -0.35$, $p < .05$.

There were also interrelations between proportion of gaze to the three different AOIs. Proportion of gaze to the experimenter was inversely related to proportion of gaze to the Jenga tower at trend level ($b = -0.31$, $p = .06$). Proportion of gaze to the room was also significantly inversely related to proportion of gaze to the toy ($b = -0.41$, $p < .05$) and inversely (but not significantly) related to proportion of gaze to the experimenter ($b = -0.28$, $p = 0.10$).

Table 5-1. Spearman's correlation table showing interrelations between demographic, behavioral, and visual attention variables of interest.

	8.	9.	10.
1. Sex	-0.07	0.29+	0.05
2. Age	0.12	-0.40*	0.02
3. BIQ total score	0.03	0.10	-0.20
4. Internalizing subscale - CBCL	-0.19	0.17	-0.04
5. Number of skipped turns	-0.27	0.00	0.22
6. Number of verbal prompts	-0.35*	0.21	0.19
7. Latency of first verbal prompt	0.35*	-0.04	-0.32+
8. Prop. of gaze to toy	--	-0.31+	-0.41*
9. Prop. of gaze to experimenter	--	--	-0.28+
10. Prop. of gaze to room	--	--	--

+p < .10, *p < .05, **p < .01, ***p < .001

Additionally, we tested whether the proportion of gaze allocated to the task (the experimenter, the Jenga tower) or away from the task (the surrounding room) moderated the relation between BI and internalizing symptoms in this sample. Further delving into the models posed by both the Dual Processing Perspective and Attentional Control Theory, we aimed to examine whether the attention that a child may deploy during a task taxing inhibitory control moderated the relation between level of BI and internalizing behaviors, thus potentially acting as a risk or protective factor.

We tested three separate models, one for each AOI (experimenter, Jenga tower, room) to examine any interactions between the child's level of BI and their attention to each AOI in relation to internalizing symptomology. We used a Poisson regression to account for the non-normal distribution, as well as count-variable nature of the internalizing subscale of the CBCL as an outcome variable. Both their BIQ score and proportion of attention to each AOI were mean-centered for these analyses.

In examining BI and attention to the room in relation to internalizing symptoms, we found no significant interactions. However, there was a significant main effect of BI, $b = 0.02$, $p < .001$.

Using the proportion of attention to the experimenter as the moderator, there were also no significant interactions with BI in relation to internalizing symptoms. Similar to the model with proportion of attention to the room, there was a significant main effect of BI, $b = 0.02$, $p < .001$.

Finally, in the model using proportion of attention to the toy, there were also no significant interactions. However there was a significant main effect of BI as in the other models, b = 0.02, $p < .001$, and also a significant negative main effect of proportion of gaze to the toy in relation to internalizing symptoms, b = -1.52, $p < .001$ (Figure 2).

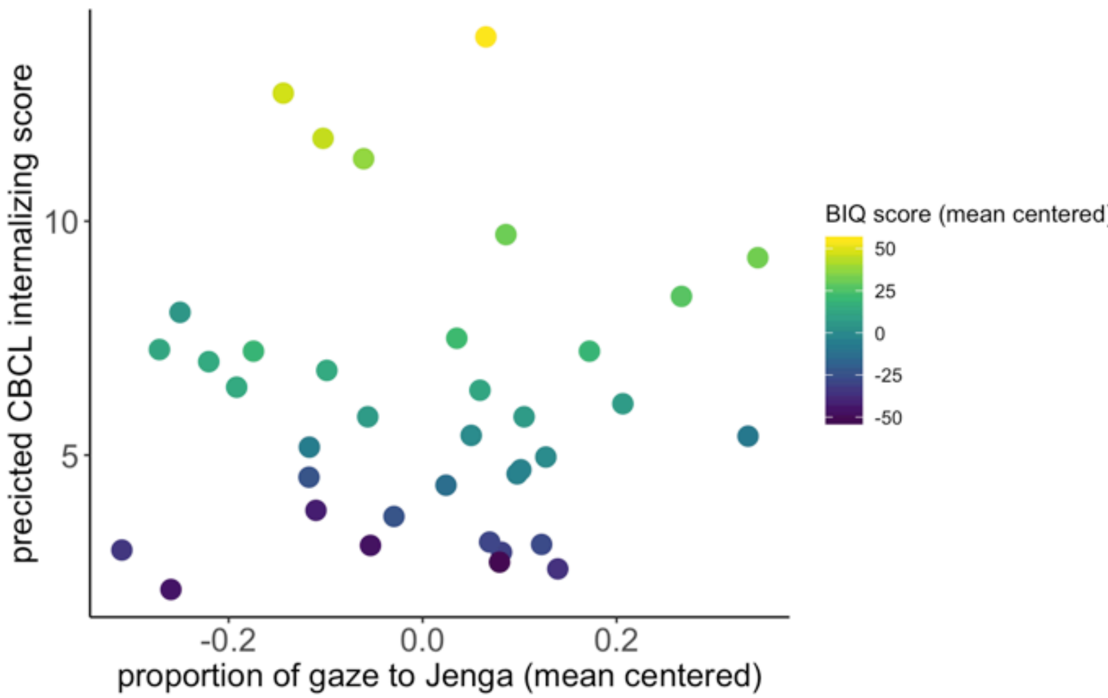

Figure 8-1. Scatterplot depicting main effect of attention to toy on internalizing symptoms

Chapter 4

Discussion

Taken together, these findings suggest that while behavior related to inhibitory control during the Tower of Patience task may not significantly moderate the relation between BI and internalizing symptomology, the way in which a child manages their visual attention during an inhibitory control task may in part relate to internalizing behaviors, regardless of level of BI.

As discussed, prior literature suggests that visual attention can act to help individuals regulate their emotions and behavior (Amso & Scerif, 2015; Rothbart et al., 2011), especially in the context of executive functions like inhibitory control (Amso & Scerif, 2015). We posited that gaze to or away from AOIs pertinent to the higher order goal of the task, for a child to wait their turn to pull a block with increasingly long wait periods, would relate to the attentional control a child was exerting to orient behavior toward this goal.

The Dual Processing Perspective suggests that high levels of controlled processing, including executive functions, may be broadly beneficial for the average child. However, for a BI child, high levels of inhibitory control specifically may exacerbate risk for internalizing symptoms by potentiating high levels of automatic processing. Patterns of automatic processing are, in turn, reflected in the attentional biases to threat that in part characterize BI children (Henderson et al., 2015; Henderson & Wilson, 2017). This model also notes that high levels of executive attention/executive functioning may not be seen in behavior, but better quantified by examining neural measures of effort.

Meanwhile, the Attentional Control Theory suggests that levels of executive functions, including inhibitory control, are negatively associated with maladaptive outcomes, like internalizing symptoms. Not unlike the Dual Processing perspective, this model also suggests that differences in goal-directed attention as a function of socioemotional difficulties, like anxiety, may not be readily apparent in simpler measures such as accuracy. Rather, they are seen in metrics of effort needed to complete the task, especially if the task is not exceptionally difficult (Eysenck et al., 2007).

In the behavioral data, the absence of a significant interaction between BI and behavioral inhibitory control, as well as no main effect of behavioral inhibitory control, in relation to internalizing symptoms are partially in line with both the Dual Processing Perspective and the Attentional Control Theory. While the level of the child's inhibitory control as operationalized by behavior during the task was unrelated to internalizing symptomology in this sample, both the Dual Processing Perspective and Attentional Control Theory emphasize that differences in levels of executive functioning, as a function of socioemotional differences, may not be reliably seen in behavioral measures, like basic accuracy. The measures entered into these models as moderators (verbal prompts, count of turn skips, and latency of first verbal prompt) may not reflect effort expended to complete the task, so according to both theories these measures may have not adequately captured individual differences (Eysenck et al., 2007).

However, there was support for the Attentional Control Theory in the mobile eye tracking data. In testing the interactions between proportions of gaze to task-relevant and task-irrelevant AOIs, there was a significant main effect of BI on internalizing symptoms in all models, consistent with previous literature on BI. Of additional note, there was a significant main effect of proportion of gaze to the Jenga blocks. While within the scope of this project we cannot infer whether attention to the Jenga blocks was a regulatory strategy, the main effect suggests that the more a child allocated attention towards the Jenga blocks, the less internalizing symptoms were reported ($b = -1.52$, $p < .001$). Critically, this relation did not change as a function of BI status. The Dual Processing Perspective predicts that high levels of inhibitory control will be a risk factor for internalizing behaviors in BI children, but a protective factor for non-BI children.

However, the finding that visual attention to a goal-linked AOI during an inhibitory control task was related to internalizing symptoms regardless of temperament supports the Attentional Control Theory.

While this study highlights the importance of novel, ecologically valid methodology in testing two different theories of how attention may relate to differences in adaptive socioemotional development, it is not without limitations. The final sample size for analysis was 37 participants, due to the number of unusable pilot participants in the greater study, as well as a conservative threshold for data quality. A small sample size may have limited power to accurately detect any potential two-way interactions in our analyses.

Additionally, there was less behavioral variability than anticipated in the task. Through the literature, the Tower of Patience task has been used for a wider spectrum of ages by framing the task as a tower building game for younger children (Buss et al., 2014; Dyson et al., 2012; Kochanska et al., 1996; Smith et al., 2013; von Suchodoletz et al., 2009) or a game of withdrawing blocks from a Jenga tower for older children (Durbin et al., 2007; Ruf et al., 2008). While studies have been published with participants as old as eight to nine years of age (Ruf et al., 2008), iterations of the Tower of Patience task have also been done in children as young as two or three years old (Buss et al., 2014; Durbin et al., 2007; Dyson et al., 2012; Kochanska et al., 1996).

In our sample, only five children (out of the coded 37) violated the turn-taking rule. It could be the case that this task was simply too “easy” for many of the five-to-seven year olds in the sample, and many children were able to inhibit a response through even the longest wait periods of the task, yielding less variability in our behavioral measures. Furthermore, this study did not include any standardized laboratory assessments of inhibitory control, to assess how these more naturalistic metrics may compare to evaluations perhaps more frequently used in the literature. While we would not necessarily expect these measures to be closely correlated because of the additional social and motivational stimuli in an ecologically valid task (Ladouce et al., 2017; Risko et al., 2017), it would provide additional insight into how these measures may compare.

Finally, more explicit measures of effort/efficiency would help to better elucidate mechanisms behind differential risk for internalizing behaviors in BI children. Using a measure of neuroimaging to capture neural efficiency in a way compatible with an ambulatory task, such as functional near infrared spectroscopy (fNIRS), may have helped to better measure individual differences on the task. Both the Dual Processing Perspective and the Attentional Control Theory suggest that efficiency may differentiate levels of executive functioning and may more strongly relate to maladaptive socioemotional outcomes than task accuracy alone. While this addition may be methodologically difficult and perhaps put additional strain on participants, asking children to self-report effort in a question like “how difficult was it for you to play this game?” also could have helped to glean additional information on different levels of effort for different children, and whether effort significantly moderated the relation between BI and internalizing symptoms.

Future directions with these data include better utilizing the repeated measures nature of both behavioral and mobile eye tracking data for microlongitudinal analytic techniques. Parsing data to repeated smaller time units and examining how these measures may change over the course of the episode would allow for the more direct examination of how behavioral violations and corresponding patterns of visual attention may change as the child is increasingly taxed by longer wait periods. These patterns may also differ across varying levels of BI and/or internalizing symptomology. By analyzing these data as repeated measures, we can also assess interrelations between in-the-moment gaze and behavior, and begin to elucidate the way in which these measures may causally interrelate. With the smaller sample size, taking advantage of these repeated measures also yields greater analytic power and a higher likelihood of accurately detecting effects.

With these methodological limitations as well as future directions in mind, this study still serves as evidence for maximizing the ecological validity of assessments of executive functioning, especially in assessing the influence of executive functioning in socioemotional development, as well as feasibility for these protocols. Moreover, these findings suggests the importance of utilizing more nuanced assessments of executive attention beyond overt behavior. In this study, visual attention patterns during an inhibitory control task was significantly related to report of internalizing symptoms, where behavior alone was not. By using measures of visual attention concurrent with an inhibitory control task, we found that attention to the Jenga blocks in the game was significantly negatively related to report of internalizing symptoms. Moreover, this relation was the same regardless of level of BI. This finding is in line with the hypotheses of the Attentional Control Theory. Taken together, these findings highlight the complexity of multifinality in socioemotional development. These findings also emphasize the importance of ecologically valid measures and multi-method approaches in quantifying and better understanding influences on development.

References

Achenback, T.M. & Edelbrock, C.S. (1983). Manual for the Child Behavioral Checklist and Revised Child Behavior Profile. Burlington: University of Vermont.

Amso, D. & Scerif, G. (2015). The attentive brain: insights from developmental cognitive neuroscience. Nature Reviews Neuroscience, 16(10), 606-619.

Amstadter, A.B., (2008). Emotion Regulation and Anxiety Disorders. Journal of Anxiety Disorders, 22(2), 211-221.

Ansari, T.L., & Derakshan, N. (2011). The neural correlates of impaired inhibitory control in anxiety. Neuropsychologia, 49, 1146-1153.

Bar-Haim, Y., Lamy, D., & Glickman, S. (2005). Attentional bias in anxiety: A behavioral and ERP study. Brain and Cognition, 59, 11-22.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. Psychological Bulletin, 121(1), 65-94.

Basten, U., Stelzel, C., & Fieback, C.J. (2011). Trait Anxiety Modulates the Neural Efficiency of Inhibitory Control. Journal of Cognitive Neuroscience, 23(10), 3132-3145.

Beesdo, K., Knappe, S., & Pine, D.S. (2009). Anxiety and Anxiety Disorders in Children and Adolescents: Developmental Issues and Implications for DSM-V.

Bishop, G., Spence, S.H., & McDonald, C. (2003). Can Parents and Teachers Provide a Reliable and Valid Report of Behavioral Inhibition? Child Development, 74(6), 1899-1917.

Broeren, S. & Muris, P. (2009). A Psychometric Evaluation of the Behavioral Inhibition Questionnaire in a Non-Clinical Sample of Dutch Children and Adolescents. Child Psychiatry & Human Development, 41(2), 214-229.

Burris, J. L., Oleas, D., Reider, L., Buss, K. A., Pérez-Edgar, K., & LoBue, V. (in press). Biased attention to threat: Answering old questions with young infants. Current Directions in Psychological Science.

Buss, K.A., Kiel, E.J., Morales, ,S., & Robinson, E. (2014). Toddler Inhibitory Control, Bold Response to Novelty, and Positive Affect Predict Externalizing Symptoms in Kindergarten. Social Development, 23(2), 232-249.

Carlson, S.M. & Moses, L.J. (2001). Individual Differences in Inhibitory Control and Children's Theory of Mind. Child Development, 72(4), 1032-1053.

Carlson, S.M. & Wang, T.A. (2007). Inhibitory control and emotion regulation in preschool children. Cognitive Development, 22, 489-510.

Chronis-Tuscano, A., Degnan, K.A., Pine, D.S., Pérez-Edgar, K., Henderson, H.A., Diaz, Y., … Fox, N.A. (2009). Stable Early Maternal Report of Behavioral Inhibition Predicts Lifetime Social Anxiety Disorder in Adolescence. Journal of the American Academy of Child & Adolescent Psychiatry, 48(9), 928-935.

Clauss, J.A., & Blackford, J.U. (2012). Behavioral Inhibition and Risk for Developing Social Anxiety Disorder: A Meta-Analytic Study. The Journal of the American Academy of Child and Adolescent Psychiatry, 51(10), 1066-1075.

Colombo, J. (1995). On the Neural Mechanisms Underlying Developmental and Individual Differences in Visual Fixation in Infancy: Two Hypotheses. Developmental Review, 15, 97-135.

Cuevas, K., & Bell, M.A. (2014). Infant Attention and Early Childhood Executive Function. Child Development, 85(2), 397-404.

Datavyu Team. (2014). Datavyu: A video coding tool. Databrary Project, New York University. Retrieved from http://datavyu.org.

Degnan, K.A. & Fox, N.A. (2007). Behavioral inhibition and anxiety disorders: Multiple levels of a resilience process. Development and Psychopathology, 19, 729-746.

Diamond, A. (2006). The early development of executive functions. In E. Bialystok & F. Craik (Eds.), Lifespan Cognition: Mechanisms of change (pp. 70-95). New York: Oxford University Press.

Durbin, C.E., Hayden, E.P., Klein, D.N., & Olino, T.M. (2007). Stability of Laboratory-Assessed Temperamental Emotionality Traits from Ages 3 to 7. Emotion, 7(2), 388-399.

Dyson, M.W., Olino, T.M., Durbin, C.E., Goldsmith, H.H., & Klein, D.N. (2012). The Structure of Temperament in Preschoolers: A Two-Stage Factor Analytic Approach. Emotion, 12(1), 44-57

Eggum-Wilkens, N.D., Reichenberg, R.E., Eisenberg, N., & Spinard, T.L. (2016). Components of effortful control and their relations to children's shyness. International Journal of Behavioral Development, 40(6), 544-554.

Eysenck, M.W., Derakshan, N., Santos, R., & Calvo, M.G. (2007). Anxiety and Cognitive Performance: Attentional Control Theory. Emotion, 7(2), 336-353.

Fitzpatrick, C., McKinnon, R.D., Blair, C.B., & Willoughby, M.T. (2014). Do preschool executive function skills explain the school readiness gap between advantaged and disadvantaged children? Learning and Instruction, 30, 25-31.

Fossati, P., Ergis, A. M., & Allilaire, J. F. (2002). Executive functioning in unipolar depression: a review. L'encéphale, 28(2), 97-107.

Franchak, J.M. & Adolph, K.E. (2010). Visually guided navigation: Head-mounted eye-tracking of natural locomotion in children and adults. Vision Research, 50(24), 2766-2774.

Franchak, J.M., Kretch, K.S., Soska, K.C., & Adolph, K.E. (2011). Head-mounted eye tracking: A new method to describe infant looking. Child Development, 82(6), 1738-1750.

Franz, L., Angold, A., Copeland, W., Costello, E.J., Towe-Goodman, N., & Egger, H. (2013) Preschool Anxiety Disorders in Pediatric Primary Care: Prevalence and Comorbidity. Journal of the American Academy of Child and Adolescent Psychiatry, 52(12), 1294-1303.

Frick, J.E., Colombo, J., & Saxon, T.F. (1999). Individual and Developmental Differences in Disengagement of Fixation in Early Infancy. Child Development, 70(3), 537-548.

Fu, X., Nelson, E. E., Borge, M., Buss, K. A., & Pérez-Edgar, K. (2019) Stationary and ambulatory attention patterns are differentially associated with early temperamental risk for socioemotional problems: Preliminary evidence from a multimodal eye-tracking investigation. Development and Psychopathology, 31, 971-988

Fu, X., & Pérez-Edgar, K. (2019). Threat-related attention bias in socioemotional development: A critical review and methodological considerations. Developmental Review, 51, 31-57.

Fu, X., Taber-Thomas, B.C., & Pérez-Edgar, K. (2017). Frontolimbic functioning during threat-related attention: Relations to early behavioral inhibition and anxiety in children. Biological Psychology, 122, 98-109.

Henderson, H.A. & Wilson, M.J.G. (2017). Attention Processes Underlying Risk and Resilience in Behaviorally Inhibited Children. Current Behavioral Neuroscience Reports, 4, 99-106.

Henderson, H.A., Pine, D.S., & Fox, N.A. (2015). Behavioral Inhibition and Developmental Risk: A Dual-Processing Perspective. Neuropsychopharmacology, 40, 207-224.

Hirshfeld, D.R., Rosenbaum, J.F., Biederman, J., Bolduc, E.A., Faraone ,S.V., Snidman, N., … Kagan, J. (1992). Stable Behavioral Inhibition and Its Association with Anxiety Disorder. Journal of the American Academy of Child & Adolescent Psychiatry, 31(1), 103-111.

Kagan, J., Reznick, J.S., & Snidman, N. (1988). Biological Bases of Childhood Shyness. Science, 240(4849), 167-171.

Kassner, M., Patera, W., & Bulling, A. (2014). Pupil: An open source platform for pervasive eye tracking and mobile gaze-based interaction. ArXiv E-Prints, 1405.

Kochanska, G., Murray, K., Jacques, T.Y., Koenig, A.L., & Vangegeest, K.A. (1996). Inhibitory Control in Young Children and Its Role in Emerging Internalization. Child Development, 67, 490-507.

Kooijmans, R., Scheres, A., & Oosterlaan, J. (2000). Response Inhibition and Measures of Psychopathology: A Dimensional Analysis. Child Neuropsychology, 6(3), 145-184.

Kretch, K.S. & Adolph, K.E. (2015). Active vision in passive locomotion: real-world free viewing in infants and adults. Developmental Science, 18(5), 736-750.

Kretch, K.S., Franchak, J.M., & Adolph, K.E. (2014). Crawling and Walking Infants See the World Differently. Child Development, 85(4), 1503-1518.

Ladouce, S., Donaldson, D.I., Dudchenko, P.A., & Ietswaart, M. (2017). Understanding Minds in Real-World Environments: Toward a Mobile Cognition Approach. Frontiers in Human Neuroscience, 10(684), 1-14.

Lahat, A., Walker, O.L., Lamm, C., Degnan, K.A., Henderson, H.A., & Fox, N.A. (2014). Cognitive conflict links behavioral inhibition and social problem solving during social exclusion in childhood. Infant and Child Development, 23, 273–282.

Lamm, C., Walker, O.L., Degnan, K.A., Henderson, H.A., Pine, D.S., McDermott, J.M., & Fox, N.A. (2014). Cognitive control moderates early childhood temperament in predicting social behavior in seven year old children: an ERP study. Developmental Science, 17(5), 667-681.

Lengua, L.J. (2003). Associations among emotionality, self-regulation, adjustment problems, and positive adjustment in middle childhood. Applied Developmental Psychology, 24, 595-618.

Lonigan, C.J., Vasey, M.W., Phillips, B.M., & Hazen, R.A. (2004). Temperament, Anxiety, and the Processing of Threat-Relevant Stimuli. Journal of Clinical Child and Adolescent Psychology, 33(1), 8-20.

May, J.G., Kennedy, R.S., Williams, M.C., Dunlap, W.P., & Brannan, J.R. (1990). Eye movement indices of mental workload. Acta Psychologica, 75, 75-89.

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., & Wager, T.D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex “Frontal Lobe” Tasks: A Latent Variable Analysis. Cognitive Psychology, 41(1), 49-100.

Morales, S., Fu, X., & Pérez-Edgar, K.E. (2016). A developmental neuroscience perspective on affect-biased attention. Developmental Cognitive Neuroscience, 21, 26-41.

Pérez-Edgar, K., Bar-Haim, Y., McDermott, L.M., Chronis-Tuscano, A., Pine, D.S., & Fox, N.A. (2010a). Attention biases to threat and behavioral inhibition in early childhood shape adolescent social withdrawal. Emotion, 10(3), 349-257.

Pérez-Edgar, K., Morales, S., LoBue, V., Taber-Thomas, B.C., Allen, E.K., Brown, K.M., & Buss, K.A. (2017). The Impact of Negative Affect on Attention Patterns to Threat Across the First 2 Years of Life. Developmental Psychology, 53(12), 2219-2232.

Pérez-Edgar, K., McDermott, J.N.M., Korelitz, K., Degnan, K.A., Curby, T.W., Pine, D.S., & Fox, N.A. (2010b). Patterns of Sustained Attention in Infancy Shape the Developmental Trajectory of Social Behavior from Toddlerhood Through Adolescence. Developmental Psychology, 46(6), 1723-1730.

Posner, M. I., & Fan, J. (2008). Attention as an organ system. In J. R. Pomerantz (Ed.), Topics in integrative neuroscience (pp. 31–61). New York: Cambridge University Press.

Posner, M.I., & Peterson, S.E. (1990). The Attention System of the Human Brain. Annual Review of Neuroscience, 13, 25-42.

Risko, E.F., Richardson, D.C., & Kingstone, A. (2016). Breaking the Fourth Wall of Cognitive Science: Real-Workd Social Attention and the Dual Function of Gaze. Current Directions in Psychological Science, 25(1), 70-74.

Rothbart, M.K., Sheese, B.E., Rueda, M.R., & Posner, M.I. (2011). Developing Mechanisms of Self-Regulation in Early Life. Emotion Review, 3(2), 207-213.

Rothbart, M.K., Ziaie, H., & O'Boyle, C.G. (1992). Self-Regulation and Emotion in Infancy. New Directions for Child Development, 55, 7-23.

Roy, A.K., Vasa, R.A., Bruck, M., Mogg, K., Bradley, B.P., Sweeney, M., … Pine, D.S. (2008). Attention Bias Toward Threat in Pediatric Anxiety Disorders. Journal of the American Academy of Child and Adolescent Psychiatry, 47(10), 1189-1196.

Rubin, K.H., Burgess, K.B., & Hastings, P.D. (2002). Stability and Social-Behavioral Consequences of Toddlers' Inhibited Temperament and Parenting Behaviors. Child Development, 73(2), 483-495.

Ruf, H.T., Schmidt, N.L., Lemery-Chalfant, K., & Goldsmith, H.H. (2008). Components of Childhood Impulsivity and Inattention: Child, Family, and Genetic Correlates. European Journal of Developmental Science, 2(1/2), 52-76.

Shackman, A.J., McMenamin, B.W., Maxwell, J.S., Greischar, L.L., & Davidson, R..J. (2009). Right Dorsolateral Prefrontal Cortical Activity and Behavioral Inhibition. Psychological Science, 20(12), 1500-1506.

Smith, H.J., Kryski, K.R., Sheikh, H.I., Singh, S.M., & Hayden, E.P. (2013). The role of parenting and dopamine D4 receptor gene polymorphisms in children’s inhibitory control. Developmental Science, 16(4), 515-530.

Suveg, C., & Zeman, J. (2004). Emotion Regulation in Children With Anxiety Disorders. Journal of Clinical Child and Adolescent Psychology, 33(4), 750-759.

Thai, N., Taber-Thomas, B.C., & Pérez-Edgar, K.E. (2016). Neural correlates of attention biases, behavioral inhibition, and social anxiety in children: an ERP study. Developmental Cognitive Neuroscience, 19, 200-210.

Thorell, L.B., Bohlin, G., & Rydell, A. (2004). Two types of inhibitory control: Predictive relations to social functioning. International Journal of Behavioral Development, 28(3), 193-203.

Toren, P., Sadeh, M., Wolmer, L., Eldar, S., Koren, S., Weizman, R., & Laor, N. (2000). Neurocognitive Correlates of Anxiety Disorders in Children: A Preliminary Report. Journal of Anxiety Disorders, 14(3), 239-247.

Underwood, G., Chapman, P., Brocklehurst, N., Underwood, J., & Crundall, D. (2003). Visual attention while driving: Sequences of eye fixations made by experienced and novice drivers. Ergonomics, 46, 629-646.

Van Ameringen, M., Mancini, C., & Oakman, J.M. (1998) The Relationship of Behavioral Inhibition and Shyness to Anxiety Disorder. Journal of Nervous & Mental Disease, 186(7), 425-431.

von Suchodoletz, A., Trommsdorff, G., Heikamp, T., Wieber, F., & Gollwitzer, P.M. (2009). Transition to school: The role of kindergarten children's behavior regulation. Learning and Individual Differences, 19, 561-566.

White, L.K., McDermott, J.M., Degnan, K.A., Henderson, H.A., & Fox, N.A. (2011). Behavioral Inhibition and Anxiety: The Moderating Roles of Inhibitory Control and Attention Shifting. Journal of Abnormal Child Psychology, 39, 735-747.

Wolfe, C.D. & Bell, M.A. (2014). Brain Electrical Activity of Shy and Non-Shy Preschool-Aged Children during Executive Function Tasks. Infant and Child Development, 23(3), 259-272.