THE DOUBLE-EDGED SWORD OF SELF-REGULATION

THE DOUBLE-EDGED SWORD OF SELF-REGULATION: DEVELOPMENTAL, TEMPERAMENTAL, AND CONTEXTUAL CONSIDERATIONS

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Lay Abstract

Self-regulation refers to children's ability to control their behavior and attention to achieve goals and is an important part of personality. Although self-regulation is typically associated with positive outcomes during the preschool period, less is known about the consequences of self-regulation during infancy, and some research has suggested that low *and* high self-regulation may have negative consequences for children. In this dissertation, I examined whether physiological regulation during infancy influenced the relation between self-regulation and behavior problems, and then I examined whether low and high levels of self-regulation are associated with children's problematic social and psychological outcomes and whether these relations depend on children's shyness and their social partner's characteristics. Together, this work challenges the belief that self-regulation is always protective for all children all the time and suggests that personality and contextual factors may determine whether self-regulation acts as a protective or a risk factor.

Abstract

Temperamental self-regulation is typically associated with adaptive outcomes, but considerably less is known about the correlates of rudimentary self-regulation—regulatory capacity—in infancy. Some theoretical frameworks also suggest that low *and* high levels of inhibitory control—one component of temperamental self-regulation—may be related to negative outcomes, and further that this may depend on individual differences in shyness. In this dissertation, I examined the functional correlates of infants' regulatory capacity moderated by physiological regulation (Chapter 2), the negative consequences of low and high levels of inhibitory control on preschoolers' social and psychological outcomes (Chapter 3), and the social (Chapter 4) and contextual (Chapter 5) factors modifying the impact of inhibitory control on shy children's interpersonal outcomes. In Chapter 2, I found that infants' regulatory capacity was only negatively related to behavior problems when infants displayed high levels of physiological regulation during an emotionally salient stressor. In Chapter 3, I found that very low and high levels of inhibitory control were related to the highest levels of avoidant social behavior and internalizing and externalizing problems in preschoolers. In Chapter 4, I found that preschoolers' shyness was only negatively associated with their own observed approach behavior when their own inhibitory control was high (actor effects), and this pattern of results differed when examining the partner's observed behavior (partner effects). In Chapter 5, I found that shyness was negatively associated with social support seeking when preschoolers displayed high levels of inhibitory control in an unfamiliar context, and this pattern of results differed in a familiar context. These studies challenge the longstanding belief that self-regulatory processes are

adaptive for all children all the time, and suggest that developmental, temperamental, and contextual factors may influence whether self-regulation acts as a resiliency or risk factor.

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Dedication

This dissertation is dedicated to my extended family who helped raise me. I will never know you as well as I should because of the great distance between us. I love you and I miss you.

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Chapter 2

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List of Abbreviations and Symbols

α: Cronbach's alpha
A: actor effect
ADC: analog to digital conversion
ANCOVA: analysis of covariance
APIM: actor-partner independence model
β: beta
BIC: Bayesian information criteria
BITSEA: Brief Infant and Toddler Social Emotional Assessment
BORIS: Behavioral Observation Research Interactive Software
CBCL: Child Behavior Checklist
CBQ: Children's Behavior Questionnaire
CFA: confirmatory factor analyses
CFI: comparative fit index
CI: confidence interval
df: degrees of freedom
ECG: electrocardiogram
EEG: electroencephalogram
FIML: full information maximum likelihood
Hz: hertz
IBQ-VSF: Infant Behavior Questionnaire-Very Short Form
κ: kappa
Lab-TAB: Laboratory Temperament Assessment Battery
ln: natural logarithm
M: mean
MCAR: missing completely at random
MLR: maximum likelihood estimation with robust standard errors
ms^2: milliseconds squared
N: total sample size
n: sample size
NIH: National Institute of Health
p: *p*-value
P: partner effect
r: Pearson correlation coefficient
RMSEA: root mean square error of approximation
RSA: respiratory sinus arrhythmia
SD: standard deviation
SE: standard error
SEM: structural equation models
SPSS: Statistical Package for the Social Sciences
SRMR: standardized root mean square residual
t: t-test statistic
T: time
X^2: Chi-square statistic

Declaration of Academic Achievement

This thesis consists of a series of empirical studies: one already published study in a scientific journal (Study 2, Chapter 3), and three studies (Study 1 in Chapter 2, Study 3 in Chapter 4, Study 4 in Chapter 5) that have been submitted for publication, two of which have been invited for revision (Study 1 in Chapter 2 and Study 4 in Chapter 5). The author of this thesis is the first author, and her supervisor, Louis A. Schmidt (McMaster University), is the last author on all manuscripts. The contributions of each author in each study are outlined below.

Hassan, R., Poole, K.L., Smith, A., Niccols, A., & Schmidt, L.A. (Under Review). Temperamental and physiological regulatory capacity in infancy: Links with toddler problem behaviors. *Invited revision.*

Study 1 (Chapter 3) examined the moderating role of infant cardiac vagal regulation on the relation between infant regulatory capacity and prospective behavior problems. Raha Hassan, the first author, conceptualized the data analyses, conducted the analyses, and wrote the manuscript. Kristie L. Poole (University of Waterloo), the second author, conceptualized the data analyses, conducted the analyses, and provided feedback on drafts of the manuscript. Ainsley Smith (McMaster University), the third author, designed the larger study, collecting the data, and provided feedback on manuscript. Alison Niccols (McMaster University), the fourth author, provided feedback on the study design and drafts of the manuscript. Louis A. Schmidt (McMaster University), the last author, provided feedback on the study design and drafts of the manuscript.

Study 2 (Chapter 3) is a reprint of the following published journal article with permission from John Wiley and Sons, Copyright © 2021:

Hassan, R. & Schmidt, L.A. (2021). Inhibitory control, dyadic social behavior, and mental health difficulties in preschoolers. *Child Development*. Advanced online publication. https://doi.org/10.1111/cdev.13725

Study 3 (Chapter 4) examined the curvilinear relation between preschoolers' inhibitory control at age 3 and observed social behaviors and maternal report of child mental health difficulties approximately one year later. Raha Hassan, the first author, conceptualized the research and experimental design, collected the data, conducted the analyses, and wrote the manuscript. Louis A. Schmidt, the last author, provided feedback on the research and experimental design and drafts of the manuscript.

Hassan, R. & Schmidt, L.A. (Under Review). Shyness and inhibitory control in preschool dyads: An actor partner model of social behavior. *Manuscript submitted for publication.*

Study 3 (Chapter 4) examined whether inhibitory control at age 3 moderated the relation between shyness at age 3 and the child's own and their social partner's behavior with an unfamiliar peer approximately one year later. Raha Hassan, the first author, conceptualized the research and experimental design, collected the data, conducted the analyses, and wrote the manuscript. Louis A. Schmidt, the last author, provided feedback on the research and experimental design and drafts of the manuscript.

Hassan, R. & Schmidt, L.A. (Under Review). Shyness, inhibitory control, and social support seeking in preschoolers: Role of familiar and unfamiliar contexts. *Invited revision*.

Study 4 (Chapter 5) examined whether contextual familiarity influenced the interaction between shyness and inhibitory control in predicting social support seeking and persistence during a model building task in preschoolers. Raha Hassan, the first author, conceptualized the research and experimental design, collected the data, conducted the analyses, and wrote the

manuscript. Louis A. Schmidt, the last author, provided feedback on the research and experimental design and drafts of the manuscript.

CHAPTER 1

General Introduction

Temperament refers to biologically based individual differences in motor, emotional, and attentional reactivity and self-regulation that influence how children interpret and interact with their world (Rothbart & Bates, 1981, 2006). During the preschool period, effortful control is the regulatory component of temperament, and captures children's ability to focus (i.e., attentional focusing) and shift their attention flexibly (i.e., attentional shifting), and control their behavior to support goal-directed actions (i.e., inhibitory control) (Rothbart et al., 2001, 2003; Rothbart & Bates, 2006). These facets of effortful control presumably function to modulate reactivity, providing the child with opportunities to overcome strong emotional experiences (Rothbart et al., 2003; Rothbart & Bates, 2006). Rothbart and her colleagues have persuasively argued that neural executive attention networks in late toddlerhood and throughout the preschool period underlie individual differences in effortful control by monitoring and resolving conflicts emerging between brain networks (Posner & Rothbart, 1998; Rothbart et al., 1994, 2003, 2007).

Developmental Course of Self-Regulation

The developmental course of effortful control follows a non-linear trajectory. From late toddlerhood to early preschool years, effortful control and its components exhibit steep increases, and then level off, exhibiting a less steep incline from late preschool to early childhood years (Dennis et al., 2007; Geeraerts et al., 2021; Klenberg et al., 2001; Kochanska et al., 1996; Schoemaker et al., 2014; Williams et al., 1999). Effortful control is rooted in a more rudimentary form of temperamental regulation called regulatory capacity (Gartstein et al., 2009, 2013; Gartstein & Rothbart, 2003). Whereas preschool effortful control is governed by neural executive attention networks, infant regulatory capacity is governed by the infant's own

orientating system and the infant's ability to be successfully regulated by external factors such as caregivers (Gartstein & Rothbart, 2003).

Positive Correlates of Self-Regulation

Self-regulation is typically regarded as positive temperamental quality. Much of the literature examining correlates of temperamental self-regulation and various social, emotional, psychological, and academic outcomes has focused on the preschool period and later in development. For example, some components of effortful control have been positively associated with domain-specific academic outcomes concurrently in preschoolers (Aram et al., 2014; Blair & Razza, 2007), kindergarteners (Ponitz et al., 2009), and adolescents (St Clair-Thompson & Gathercole, 2006), and prospectively from preschool to kindergarten (McClelland et al., 2007) and preschool to early childhood (Neppl et al., 2020). Effortful control has also been related to domains that are important for children's interpersonal success. For example, effortful control and related constructs have been consistently and positively related to prosocial tendencies (Diener & Kim, 2004; Eisenberg et al., 1995, 1997; 2007; Rothbart et al., 2001), the emergence of self-consciousness, including emotional experiences such as empathy (Eisenberg, 2010) and guilt (Kochanska & Aksan, 2006), and effective modulation of emotional expressions (Kochanska et al., 2000). Concerning psychological functioning, different conceptualizations of self-regulation typically have been negatively associated with externalizing difficulties in preschoolers (Olson et al., 2005; Petitclerc et al., 2015), and in preadolescent (Rapport et al., 1986) and adolescent boys (Krueger et al., 1996), and fewer internalizing problems during early and late childhood (Eisenberg et al., 2009; B. A. White et al., 2013). Comparatively less is known about the correlates of infant regulatory capacity, although regulatory capacity has been negatively associated with internalizing difficulties in infancy (Wittig & Rodriguez, 2019) and

early childhood (Gartstein et al., 2012) and positively associated with some aspects of school readiness (Gartstein et al., 2016).

Theoretical Frameworks Challenging the "More is Better" Approach to Self-Regulation

Despite the associations noted between temperamental self-regulation and various positive outcomes in different domains of functioning reviewed above (Aram et al., 2014; Blair & Razza, 2007; Diener & Kim, 2004; Eisenberg, 2010; Eisenberg et al., 1995, 1997, 2009; Gartstein et al., 2012, 2016; Kochanska et al., 2000; Kochanska & Aksan, 2006; Krueger et al., 1996; McClelland et al., 2007; Olson et al., 2005; Petitclerc et al., 2015; Ponitz et al., 2009; Rapport et al., 1986; Rothbart et al., 2001; St Clair-Thompson & Gathercole, 2006; B. A. White et al., 2013; Wittig & Rodriguez, 2019), several theoretical accounts have proposed that very low *and* high levels of some aspects of effortful control, inhibitory control in particular, may have negative consequences for children (Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992). Inhibitory control refers to one's ability to inhibit a prepotent, easily accessible response in favor of activating a less dominant, less accessible response, and is a key component of temperamental effortful control during the preschool period (Rothbart et al., 2001, 2003; Rothbart & Bates, 2006). Collectively, these theoretical frameworks suggest low levels of inhibitory control may be associated with social and psychological difficulties because of increased emotional lability, inability to delay gratification, impulsivity, and a socially inappropriate behavioral presentation, whereas high levels of inhibitory control may be associated with social and psychological difficulties because of excessive inhibition of behavior, impulses, emotions, and desires leading to an unnecessary denial of pleasure and a constrained behavioral presentation (Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992).

Several empirical studies have provided support for the theoretical frameworks suggesting that intermediate levels of inhibitory control may be associated with the most optimal outcomes (Carlson & Wang, 2007; Eisenberg et al., 2002; Murray & Kochanska, 2002; Robins et al., 1996), but there have been several important gaps worth noting. First, these studies have focused on impulsivity (Eisenberg et al., 2002), over- and under-control (Martel et al., 2007; Robins et al., 1996), and effortful control (Murray & Kochanska, 2002), but theoretical accounts of the potentially negative impacts of "too much" self-regulation focus on descriptions depicting inhibitory control specifically (Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992). Relatedly, these studies have failed to consider children's observed social behavior with a peer, and this is an important gap because too little and too much inhibitory control should theoretically be associated with different behavioral presentations that may have consequences for how children behave with their peers (Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992).

The Risk Potentiation Model of Control: Shyness and Inhibitory Control

High levels of inhibitory control may be particularly problematic for temperamentally shy children. Temperamental shyness refers to children's tendency to experience fear and react with inhibition and avoidance when faced with social novelty, and is typically associated with problematic outcomes (Kagan et al., 1988; Karevold et al., 2012; Sanson, 1996). Similar to the theoretical accounts proposing that very low *and* high levels of inhibitory control will have negative consequences for children (Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992), the risk potentiation model of control suggests that inhibitory control may act as a risk factor for temperamentally reactive children, such as those who are shy (Henderson et al., 2015; Henderson & Wilson, 2017). To help regulate the negative emotions

associated with shy children's automatic orientation towards the perceived threat, the controlled processing network is frequently recruited and functions to potentiate, rather than eliminate, the fear already present (Henderson et al., 2015; Henderson & Wilson, 2017). Over time, the combination of frequently activating both the reactive and controlled modes of processing presumably creates a positive feedback loop where fear is reinforced (Henderson et al., 2015; Henderson & Wilson, 2017). Here, shy children spend more time monitoring their environment, perceive more social threat in their environment, and therefore are more likely to engage in "overregulated" behavioral responses and distorted cognitive perceptions, such as displaying blunted affect or being socially disengaged.

While there is empirical support for the risk potentiation model of control in the context of shyness and temperamental styles related to shyness, including reactive temperament, behavioral inhibition, and social fear (Brooker et al., 2016; Henderson, 2010; Lahat et al., 2014; Lamm et al., 2014; Poole et al., 2021; Rodrigues et al., 2021; Sette et al., 2018; Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011), there are several important gaps that should be highlighted. Similar to the gaps in the literature examining the curvilinear relation between inhibitory control and children's outcomes, most work has relied on parent or teacher report of outcomes rather than observed behavior (Henderson, 2010; Poole et al., 2021; Rodrigues et al., 2021; Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011). It is important to include measures of observed behavior during interactions with peers because the risk potentiation model of control makes predictions about children's social behavior, and parent reports of social behavior may not align with how children truly behave with their peers (Henderson et al., 2015; Henderson & Wilson, 2017).

Second, although previous studies have examined the influence of shyness and inhibitory control on the child's own outcomes (i.e., actor effects), we do not have information about how one child's shyness and inhibitory control influences the way another child reacts to the target child (i.e., partner effects). This is an important gap to consider because children's social interactions involve at least two people and are dynamic. It is possible that the negative consequences of relatively high levels of shyness and inhibitory control are constrained to the child's own behavior, and other children positively compensate for the shy and inhibited child's behavior.

Third, it remains unclear whether social contextual familiarity influences the relation among shyness, inhibitory control, and social outcomes. Shyness is defined as wariness in the context of social *novelty*, and so it is possible that the risk potentiation model of control may depend on the familiarity of the social interaction partner (Buss, 1986; Cheek & Buss, 1981; Karevold et al., 2012; Sanson, 1996). If the negative impact of high shyness and inhibitory control was specific to an unfamiliar context, then the adaptiveness of inhibitory control for shy children could be manipulated by increasing contextual familiarity, potentially improving shy children's outcomes.

Overview of Dissertation

Considering the gaps in the extant literature, this dissertation broadly examines the correlates of a developmental antecedent of preschool temperamental self-regulation in infancy and then examines the contexts in which self-regulation acts as a resiliency versus a risk factor. In a series of four empirical studies, I used a multi-method approach cross-sectionally and longitudinally and across developmental time to examine the correlates of temperamental self-regulation in infancy, and then examine the curvilinear relation between inhibitory control and

outcomes independently, and then examine the negative impact of high inhibitory control on children's social behavior while considering temperamental, social, and contextual factors that may modify these relations during the preschool period.

In Chapter 2 (Study 1), I examined whether infants' physiological regulation during different phases of a standardized stressor moderated the association between infant regulatory capacity at 8 months and behavior problems at 14 months. I found that regulatory capacity was only negatively related to prospective behavior problems when infants displayed relatively high levels of physiological regulation from baseline to a stressor. These results suggest that an early antecedent of temperamental self-regulation in infancy is not always related to fewer psychological problems, and that physiological self-regulation may facilitate access to more effective self-regulation resulting in fewer behavioral problems in the future.

In the remaining three empirical chapters (Chapters 3, 4, and 5), I examined the limits of the adaptiveness of inhibitory control, one component of temperamental self-regulation during the preschool period, independently (Chapter 3), when considering shyness and social interactions with an unfamiliar peer (Chapter 4), and when manipulating the familiarity of a social context by considering shyness and social support seeking with a familiar versus unfamiliar adult (Chapter 5).

In Study 2 (Chapter 3), I empirically evaluated longstanding theoretical frameworks suggesting that the relation between inhibitory control and social and psychological outcomes may be curvilinear. Using a longitudinal design, I examined whether a multimethod index of inhibitory control at age 3 displayed a U-shaped relation with observed social behavior with an unfamiliar peer and maternal report of psychopathology at age 4.5. I found that age 3 inhibitory control displayed a U-shaped relation with age 4.5 outcomes, where children with low *and* high

inhibitory control had relatively higher levels of avoidant social behavior and mental health difficulties. These results suggest that inhibitory control is not a panacea and that both over and underregulation can have negative consequences for children.

In Study 3 (Chapter 4) and Study 4 (Chapter 5), I tested the limits of the risk potentiation model of control which suggests that high levels of inhibitory control may be particularly problematic for shy children. In Study 3, I examined whether a multimethod index of inhibitory control at age 3 moderated the relation between shyness measured at age 3 and the child's own and their social partner's behavior with an unfamiliar peer at age 4.5. Consistent with the risk potentiation model of control, I found that children's shyness was only negatively associated with children's own observed approach behavior when their own inhibitory control was relatively high. I also found that when children's inhibitory control was relatively low, children's shyness was positively related to their partner's observed avoidance behavior, but when children's inhibitory control was relatively high, shyness was negatively associated with their partner's observed avoidance behavior. These results suggest the "negative" consequences of being highly shy and overcontrolled may be limited to the child's own behavior, and not necessarily reflected in how unfamiliar children respond to that child in a social context.

In Study 4 (Chapter 5), I examined whether the moderating role of inhibitory control on the relation between shyness and social support seeking differed in social interactions with the child's mother (i.e., a familiar context) versus an adult female research assistant whom the child had never met before (i.e., an unfamiliar context). Consistent with the risk potentiation model of control, I found that shyness was only negatively associated with social support seeking at high levels of inhibitory control in the unfamiliar condition. However, in the familiar condition, I found that shyness was only positively associated with social support seeking at high levels of

inhibitory control. Like Study 3, these results suggest the "negative" consequences of being highly shy and overcontrolled may be limited to an unfamiliar social context.

Collectively, my program of research suggests self-regulation is not always protective. I demonstrated that in infancy, rudimentary regulatory capacity was only protective against prospective behavior problems when infants also displayed relatively high levels of physiological regulation, but not when infants displayed relatively low levels of physiological regulation. During the preschool period, only intermediate levels of inhibitory control were prospectively associated with low levels of avoidant social behavior and mental health difficulties, and both low *and* high levels of inhibitory control were associated with problematic social and psychological outcomes. Further, in examining the limits of the risk potentiation model of control, the negative impact of relatively high levels of inhibitory control may also depend on temperament and social context during the preschool period. More specifically, shyness was negatively associated with children's own prospective observed approach behavior when their inhibitory control was high, but children's shyness was negatively related to their partner's observed avoidance behavior when their inhibitory control was relatively high, and positively associated with their partner's observed avoidance behavior when their inhibitory control was relatively low. Similarly, shyness was only negatively associated with social support seeking at high levels of inhibitory control in an unfamiliar context but positively associated with social support seeking at high levels of inhibitory control in a familiar context. Together, these studies highlight the contexts in which self-regulation acts as a knife that cuts on both sides.

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CHAPTER 2

Study 1: Temperamental and physiological regulatory capacity in infancy: Links with toddler behavior problems

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Abstract

Although correlates of temperamental regulatory processes in childhood have been well established, there is considerably less work examining correlates and moderators of rudimentary forms of temperamental regulation in infancy. We examined whether infants' physiological regulation indexed via changes in respiratory sinus arrhythmia (RSA) across phases of the Still-Face Paradigm moderated the association between maternal-reported infant regulatory capacity at 8 months (N = 50, M_{age} = 8.51 months, SD_{age} = 0.28 months, 25 girls) and behavior problems at 14 months. We found that cardiac vagal regulation from baseline to still-face moderated the relation between infant regulatory capacity at 8 months and behavior problems at 14 months. Among infants who displayed relatively high cardiac vagal regulation from baseline to still-face, regulatory capacity was negatively associated with behavior problems at 14 months. There was no relation between regulatory capacity and behavior problems among infants who displayed average or relatively low cardiac vagal regulation. We speculate that high levels of regulatory capacity and cardiac vagal regulation may allow infants to focus their attention outward and cope with emotionally evocative environmental demands as they arise.

Keywords: regulation; respiratory sinus arrhythmia; infancy; behavior problems

Introduction

Temperament from infancy to childhood is characterized by individual differences in dispositional reactivity and regulation that are influenced by interactions among biological, genetic, and environmental factors (Rothbart & Bates, 2006; Shiner et al., 2012). In early childhood, effortful control is the regulatory component of temperament and it involves children's ability to focus and shift their attention flexibly and control their behavior to support goal-directed actions (Rothbart et al., 2001, 2003; Rothbart & Bates, 2006). Effortful control and its components have been linked to adaptive academic, social, and psychological outcomes. For example, effortful control has been related to relatively higher domain-specific academic outcomes in preschoolers (Aram et al., 2014; Blair & Razza, 2007), kindergarteners (Ponitz et al., 2009), and adolescents (St Clair-Thompson & Gathercole, 2006), relatively higher prosocial tendencies across childhood (Diener & Kim, 2004; Eisenberg et al., 1995, 1997; 2007; Rothbart et al., 2001), and relatively lower levels of externalizing behavior problems in preschoolers (Olson et al., 2005; Petitclerc et al., 2015) and preadolescents (Krueger et al., 1996; Rapport et al., 1986), and fewer internalizing problems during early and late childhood (Eisenberg et al., 2009; White et al., 2013). However, relations between more fundamental forms of infant temperamental self-regulation and children's later behavior problems are less well understood.

Effortful control in childhood has its roots in a more rudimentary form of temperamental regulation referred to as regulatory capacity or orienting (Gartstein et al., 2009, 2013; Gartstein & Rothbart, 2003; Putnam et al., 2008). While effortful control is governed primarily by neural executive attention networks working to monitor and resolve conflicts emerging between brain networks (Posner & Rothbart, 1998; Rothbart et al., 1994, 2003, 2007), infant regulatory capacity is governed primarily by the orienting system and the ability to be successfully

regulated by caregivers (Gartstein & Rothbart, 2003). Like effortful control, infant regulatory capacity appears to set the stage for more adaptive developmental outcomes. For example, infant regulatory capacity is negatively associated with internalizing difficulties in infancy (Wittig & Rodriguez, 2019) and early childhood (Gartstein et al., 2012) and positively associated with some aspects of school readiness (Gartstein et al., 2016).

Although dispositional or trait infant regulatory capacity appears to be positively related to developmental outcomes (Gartstein et al., 2012, 2016; Wittig & Rodriguez, 2019), the interactive role of trait and state self-regulation remains less clear. It is possible that not all infants with high trait regulatory capacity in infancy experience the same levels of state-related regulation in response to an emotionally salient stressor, and state-related regulation may modify infants' ability to access adaptive emotional regulatory strategies and behavioral responses thereby influencing subsequent outcomes. These relations can be understood within a cognition-emotion framework. The separation of state versus trait regulatory capacity may be particularly relevant during infancy when regulatory capacity is in part comprised of seeking contact with caregivers through cuddliness and successfully being soothed by others, as well as cognitive factors such as duration of orientating, whereas later temperamental effortful control is driven comprised of the child's ability to regulate their behavior and attention (Rothbart & Bates, 2006). During infancy, state-related physiological regulation during emotionally evocative situations reflecting changes in arousal may allow children to access their dispositional regulatory capacity.

Infants' state-related physiological regulation during stressors indexed via changes in respiratory sinus arrhythmia (RSA) may influence the relation between trait regulatory capacity and problematic outcomes. RSA reflects variability in heart rate occurring at the frequency of respiration and is thought to index the parasympathetic nervous system's influence on the heart

through the vagus nerve (Porges, 2007). Much of the recent work on RSA has been guided by polyvagal theory (Porges, 1995, 2007), which suggests that the development of the parasympathetic nervous system supports individuals' capacity for engagement with environmental demands. Porges suggests that in response to personally and emotionally evocative environmental stimuli, the regulation of emotional and social states occurs through the regulation of cardiac activity. Typically, RSA has been measured at rest (i.e., baseline), during a task/stressor, or in the form of change scores such as from baseline to a stressor (i.e., cardiac vagal regulation).

Cardiac vagal regulation can provide us with information about individual differences in reactivity and regulation. When faced with environmental challenges, individuals typically react with either cardiac vagal augmentation (baseline-to-task increases in RSA) or withdrawal (baseline-to-task decreases in RSA) (Hastings & Kahle, 2019). Cardiac vagal augmentation is thought to support a relatively calm state and is activated when environmental stimuli are personally relevant and potentially challenging, but not threatening, whereas cardiac vagal withdrawal is thought to support a more alert and orienting state and is activated when environmental stimuli are personally relevant and potentially threatening.

Cardiac vagal regulation in the form of either augmentation or withdrawal, depending on the context, is thought to support potentially more adaptive and flexible emotional and behavioral responses in the face of environmental challenges (Calkins, 1997; Calkins et al., 2007; Hastings & Kahle, 2019; Porges, 2001, 2003). Accordingly, individual differences in infants' state-related physiological regulation in the face of an environmental stressor may influence infants' ability to flexibly respond to environmental demands and may interact with trait levels of regulatory capacity.

Several investigators have examined the moderating role of cardiac vagal regulation on the relation between child- or environmental-level factors and various areas of development. Of note, very few studies have focused on this relation in infancy. In one study, temperamental exuberance was positively related to externalizing difficulties in 24-month-old girls who displayed cardiac vagal withdrawal, but not in girls who displayed cardiac vagal augmentation (Morales et al., 2015). Similarly, in a sample of 5-year-old children, sociodemographic risk was negatively related to school readiness only when cardiac vagal withdrawal was relatively low (Propper et al., 2021). In a different sample of preschoolers, non-supportive maternal reactions to children's negative emotions were negatively associated with children's observed and parent-reported emotion regulation only at relatively low cardiac vagal withdrawal, but not at relatively high levels of cardiac vagal withdrawal (Perry et al., 2012). Similarly, relatively higher levels of cardiac vagal withdrawal were protective against internalizing difficulties among adolescents who were from homes with high levels of marital discord (El-Sheikh & Whitson, 2006; Khurshid et al., 2019). Results of these studies collectively suggest that relatively high levels of vagal withdrawal may promote children's ability to effectively cope with environmental stressors and that individual differences in vagal regulation may modify the relation between child-level factors such as temperament and problematic outcomes.

There are, however, several gaps in the literature. First, compared to studies examining effortful control in toddlerhood and beyond (Aram et al., 2014; Blair & Razza, 2007; Diener & Kim, 2004; Eisenberg et al., 1995, 1997, 2009; Krueger et al., 1996; Olson et al., 2005; Petitclerc et al., 2015; Ponitz et al., 2009; Rapport et al., 1986; Rothbart et al., 2001; St Clair-Thompson & Gathercole, 2006; White et al., 2013), there is considerably less work examining outcomes related to regulatory capacity in infancy (Gartstein et al., 2012, 2016; Wittig & Rodriguez,

2019). This is a gap that should be addressed because effortful control in toddlerhood is rooted in more rudimentary infant regulatory capacity (Gartstein et al., 2009, 2013; Gartstein & Rothbart, 2003; Putnam et al., 2008), and regulatory difficulties beginning in infancy may set the stage for later behavior problems and mental health difficulties (Briggs-Gowan et al., 2006; Keenan et al., 1998; Shaw et al., 2003). Second, the lack of research integrating state-related changes in physiological reactivity with trait-related regulatory capacity assumes that all children with relatively high levels of trait regulatory capacity are equally able to regulate in the face of emotionally salient environmental challenges. However, given the assumptions of polyvagal theory (Porges, 1995, 2007), it is possible that cardiac vagal regulation interacts with trait levels of regulatory capacity to enable infants to access the strategies they are most likely to use given their temperamental disposition. This may be particularly relevant during infancy in contexts where the infant cannot use caregivers to help regulate because temperamental regulation during infancy includes the ability to be soothed by others and make physical contact with caregivers. Third, the research integrating the moderating role of cardiac vagal regulation (El-Sheikh & Whitson, 2006; Khurshid et al., 2019; Morales et al., 2015; Perry et al., 2012; Propper et al., 2021) has focused largely on developmental periods beyond infancy.

Considering these gaps, the goal of the present study was to examine whether infants' physiological regulation indexed via changes in RSA from baseline to a stressor moderated the association between infant regulatory capacity at 8 months and behavior problems at 14 months. RSA was selected as a measure of state physiological regulation because of the strong theoretical basis for its use as an index of physiological regulation (Porges, 1995, 2007) and because it can be passively collected while the infant is exposed to an emotionally evocative stimulus. We elected to use the Still-Face Paradigm as a context to examine infant's physiological regulation

because it has been used reliably as an emotionally salient stressor for infants for over 45 years and the standardized phases allow for the observation of infants' physiological reactions to a play baseline and stressor induction (Mesman et al., 2009). To the extent that regulatory capacity is supported by cognitive processes and cardiac vagal regulation during an evocative stressor represents an emotional response, the present study is well positioned to examine the interaction between cognition and emotion. Given previous research results showing the advantages of relatively high levels of cardiac vagal withdrawal (El-Sheikh & Whitson, 2006; Khurshid et al., 2019; Morales et al., 2015; Perry et al., 2012; Propper et al., 2021), we predicted that infants' trait regulatory capacity would be negatively associated with behavior problems in toddlerhood at relatively high levels of cardiac vagal withdrawal from baseline to the stressor.

Method

Participants

Participants were 50 typically developing 8-month-old infants (25 girls, M_{age} = 8.51 months, SD_{age} = 0.28 months) and their mothers. All but one of the mothers reported being a part of a dual-parent household, and the majority (80%) of mothers had mean annual combined household income of $80,000 or greater in Canadian dollars. Infants and their mothers were recruited from the Child Database at McMaster University. This database contains the names and contact information of parents of healthy, full-term newborn infants recruited from hospitals across the greater Hamilton metropolitan area who consented to participate in future infant and child studies conducted at McMaster University.

Procedure

Mothers and their infants were tested in the Child Emotion Laboratory at McMaster University when the infants were 8 months old. The present study was part of a larger

investigation examining the behavioral and physiological correlates of infant and toddler mental health. Upon arrival at the laboratory, the infant and mother were greeted by two researchers. The objectives and procedures of the study then were described to the mother while the infant had a chance to explore and acclimate to the laboratory playroom. Following informed consent, infant baseline electrocardiogram (ECG) data were collected while the infant watched a quiet 5-minute video. The infant and mother then participated in the three phases of the Still-Face Paradigm (Tronick et al., 1978), described below, while infant ECG data were collected. Finally, the mother was asked to complete questionnaires using an iPad while the infant remained in the same room. Mothers received a $20 gift card in Canadian dollars as remuneration for their participation in the laboratory visit. Follow-up questionnaires were completed online by the mothers when the infants were 14 months old, and mothers received a $10 gift card in Canadian dollars for their participation for the follow-up assessment. All procedures were approved by the McMaster Research Ethics Board.

Maternal-Report Measures

Infant Regulatory Capacity (8 months). The Infant Behavior Questionnaire-Very Short Form (IBQ-VSF) is a parent report measure used to assess infant temperament where parents rate items on a scale of 1 (never) to 7 (always) (Putnam et al., 2014). Of particular interest to the present study were maternal ratings on the regulatory capacity scale. An example of an item on this scale includes “How often during the last week did the baby look at pictures in books and/or magazines for 5 minutes or longer at a time?”. Higher values on this scale are indicative of higher regulatory capacity. This scale demonstrated good internal consistency ($\alpha = .79$).

Behavior problems (14 months). The Brief Infant and Toddler Social Emotional Assessment (BITSEA) is a parent-report measure used to assess social-emotional problems and

social competencies in children aged 12 to 48 months (Briggs-Gowan, 2004). Parents rate items on a scale of 1 (strongly agree) to 5 (strongly disagree). Of particular interest to the present study was maternal ratings of the behavior problems scale. An example of an item on this includes "Seems nervous, tense, or fearful". Higher values on this scale are indicative of higher levels of behavior problems. This scale demonstrated acceptable internal consistency ($\alpha = .60$).

Still-Face Paradigm

The Still-Face Paradigm is a well-validated laboratory task to elicit stress in infants (Mesman et al., 2009; Tronick et al., 1978). The task is comprised of a total of three phases including a baseline play phase, still-face phase, and reunion phase. The focus of the present study was physiological changes from the baseline play face to the still-face phase. During this task, the infant was placed in a highchair across from the mother and the still-face procedure was explained to the mother by the researcher. During the play phase, mothers were instructed to play with their infants as they normally would in the home for two minutes. This phase acted as a baseline for the still-face. During the still-face phase, mothers were instructed to display a neutral face and refrain from touching or speaking to the infant for two minutes. This phase acted as a stressor. During the reunion phase, mothers were again instructed to interact with their infant as normal for two minutes. This phase acted as a recovery period to ensure the infant finished the task on a positive note. The mother was signaled about the episode change by the flashing of a small light on the testing room wall in front of her, out of sight of her infant. If the infants engaged in more than 30 s of continuous crying in the baseline play phase, the procedure was stopped, and the mother was able to remove the baby from the highchair to provide comfort. The Still-Face Paradigm was attempted again if the infant was soothed. If the infant engaged in more than 30 s of continuous crying during the still-face episode, the episode was ended early, and the

mother moved on to the reunion episode. If the infant continued to cry, the procedure was ended early.

Electrocardiogram (ECG)

Data Collection. Cardiac and respiratory data were collected using the MindWare Mobile Impedance Cardiograph, Model 50-2303-00, with a sampling rate of 500 Hz and 24-bit ADC digitization. Cardiac data were recorded from three electrodes affixed to the infant's back in an inverted triangle pattern. Respiration data were recorded from a respiratory strain gauge placed around the infant's chest. RSA data were collected across the phases of the Still-Face Paradigm (Tronick et al., 1978).

Data Reduction and Quantification. The cardiac and respiratory signals were reduced and analyzed using a commercial software package (MindWare HRV 3.1.1, MindWare Technologies, Ltd.), and edited by hand for spurious or missing beats (Berntson & Stowell, 1998). We used a respiratory frequency of 0.24 to 1.04 Hz. RSA (*ln* ms^2). RSA was estimated by averaging the mean RSA from two 1-minute-long segments from the two phases of interest during the Still-Face Paradigm. Cardiac vagal regulation was operationalized as RSA during the play phase minus the still-face phase. Higher values on this metric were indicative of relatively higher cardiac vagal withdrawal and therefore higher cardiac vagal regulation.

Missing Data

Three infants had missing baseline RSA data due to excessive artifact (n = 2) and data recording failure (n = 1). Four infants did not complete the Still-Face Paradigm due to high levels of infant distress during the baseline play phase. Of the 46 mother-infant dyads that began the Still-Face Paradigm, 7 infants had missing RSA data during the different stages of the Still-Face Paradigm due to excessive artifact (n = 6) and data recording failure (n = 1). One infant had

missing data on maternal report of temperament because of an incomplete questionnaire. Due to overlap in missing data, 14 infants were missing data on at least one variable.

Five families were lost to follow up at 14 months (n = 45, i.e., 90% retention from 8 to 14 months). Missingness at 14 months was not associated with infant regulatory capacity $t(47) = 0.71$, $p = .483$ or cardiac vagal regulation, $t(34) = 1.05$, $p = .301$.

Little's test of Missing Completely at Random (MCAR) was not significant, $\chi 2 = 13.13$, $df = 16$, $p = .66$, suggesting that patterns of missing data did not violate the assumption that data were missing completely at random. To leverage the complete sample (N = 50) and avoid the biased parameter estimates that can occur with pairwise or listwise deletion (Schafer & Graham, 2002), we imputed missing data using the expectation-maximization algorithm for children with data on at least one variable at the 8- or 14-month visit. Of note, results using listwise deletion produced statistically similar results.

Statistical Analyses

We examined relations among all study variables using Pearson correlations. Model 1 of PROCESS' SPSS macro was used to determine whether 8-month cardiac vagal regulation moderated the association between 8-month regulatory capacity and 14-month behavior problems, controlling for baseline play RSA. The analyses were conducted using SPSS Version 28, with the significance level set at $\alpha = .05$.

Results

Descriptive Information

Outliers were Winsorized, and all variables were evaluated for normality using skewness and kurtosis statistics. Table 1.1 presents the correlations and descriptive statistics for the study

variables. Infant regulatory capacity at 8 months was not correlated with cardiac vagal withdrawal or prospective problem behaviors at 14 months.

Cardiac Vagal Regulation

The model, $F(4, 45) = 2.35$, $p = .068$, $R^2 = .17$, described in Table 1.2, revealed a significant interaction between infant regulatory capacity and cardiac vagal regulation from the play phase to the still-face phase, controlling for play baseline RSA, in predicting later behavior problems ($\beta = -2.87$, $p = .010$, 95% CI = -5.03 to -0.71).

To probe this interaction, we calculated the slope of infant regulatory capacity at high (one standard deviation above the mean), average (mean) and low (one standard deviation below the mean) values of cardiac vagal regulation. In infants who displayed high cardiac vagal regulation from baseline play to still-face, infant regulatory capacity was significantly negatively associated with later behavior problems ($\beta = -2.27$, $p = .02$, 95% CI = -4.21 to -0.33; See Figure 1). Infant regulatory capacity was not significantly associated with later problem behaviors at average ($\beta = -0.31$, $p = .61$, 95% CI = -1.51 to 0.90) and low ($\beta = 1.65$, $p = .08$, 95% CI = -0.21 to 3.51) levels of cardiac vagal regulation.

Discussion

Early in development, infant regulatory capacity sets the stage for later effortful control (Gartstein et al., 2009, 2013; Gartstein & Rothbart, 2003). In infancy, regulatory capacity is comprised of early markers of infant cognition, including duration of orienting and ability to be soothed and seek comfort from external caregivers (Gartstein & Rothbart, 2003). Although regulatory capacity is considered a resiliency factor against the development of later mental health difficulties (Gartstein et al., 2012; Wittig & Rodriguez, 2019), there has been a lack of research integrating trait- and state-related differences in physiological regulation in predicting

later behavior problems. The goal of the present study was to examine if cardiac vagal regulation from a baseline to a stressor during the Still-Face Paradigm (Tronick et al., 1978) moderated the association between maternal report of infant regulatory capacity at 8 months and behavior problems at 14 months. Infant regulatory capacity was negatively related to prospective behavior problems only when infants displayed relatively high cardiac vagal regulation (i.e., withdrawal) from baseline play to still-face. Infant regulatory capacity was not significantly related to later behavior problems when cardiac vagal regulation was average or low.

Examining changes in RSA from the baseline play phase to the still-face phase provides an opportunity to index how infants respond physiologically to an emotionally salient and personally threatening context. In the face of this threat, it is expected that infants will experience a lowering of parasympathetic activity indexed via reductions in RSA resulting in increases in arousal (Hastings & Kahle, 2019; Porges, 2003). Increases in arousal in response to an environmental challenge allow infants to orient towards the threat and dedicate resources to flexibly respond to the challenge. Given that infant regulatory capacity comprises early markers of attention focusing (i.e., duration of orientating), we speculate that relatively higher levels of cardiac vagal withdrawal allow infants to capitalize on their trait regulatory capacity by flexibly orienting towards the environmental challenge, displaying a readiness to respond to and manage threats. Given the positive relations observed between cardiac vagal withdrawal and emotion regulation (e.g., Gentzler et al., 2009), infants who have relatively higher infant regulatory capacity and display higher cardiac vagal withdrawal in response to a stressor display more effective emotion regulation.

To the extent that regulatory capacity reflects early markers of self-regulatory cognitive processes and cardiac vagal regulation reflects the body's attempts to regulate negative emotions

during a stressful task, the results from the present study can be interpreted within a cognitive-emotion framework. The context under which these were observed should also be considered. The still face phase of the Still-Face Paradigm asks mothers to maintain a neutral facial expression while the infant is in a highchair and unable to physically access their mother. Here, the mother is not helping the infant regulate their emotions and the infant must instead rely on their independent top-down processes to cope. Because temperamental self-regulation in infancy is in part comprised of external regulation from caregivers, state-related physiological processes such as cardiac vagal regulation may be particularly important in the absence of external regulation. These processes may appropriately increase the infant's arousal to support orientation towards the threat and allow for the dedication of cognitive resources to flexibly respond to the challenge. Infants with relatively high trait regulatory capacity *and* high cardiac vagal regulation may display fewer problem behaviors later in development because this combination of state and trait regulation reflects more effective coping in stressful situations even in the absence of external regulation from caregivers.

Strengths, Limitations, and Future Directions

Although the present study had several strengths, including a longitudinal design, the inclusion of both trait and physiological state measures of regulatory capacity, and the investigation of self-regulatory processes in infancy, several limitations should be acknowledged. First, infant regulatory capacity and behavior problems were both maternally reported, which may be more susceptible to bias than observational measures. However, the IBQ and BITSEA are widely used measures of infant temperament and difficulties (Briggs-Gowan, 2004; Putnam et al., 2014). Second, the sample was relatively small and homogeneous, consisting primarily of educated families with relatively high annual income and 14-month-olds with relatively low

levels of behavior problems. Accordingly, our results may not generalize to other populations. However, it is also important to point out that retention was excellent, and we were able to detect individual differences in 14-month behavior problems that were predicted by infant regulatory capacity and cardiac vagal regulation, suggesting the sensitivity of our measures to detect effects even in a small and homogeneous sample. Further, there has been an increase in studies moving beyond difference scores to examine dynamic changes in RSA (Brooker & Buss, 2010; Cui et al., 2015; Davis et al., 2020; Kiel et al., 2021; Miller et al., 2013). We focused on difference scores in the present study because we were underpowered to use growth models to examine dynamic patterns of RSA change. Finally, the internal consistency for the behavior problems scale was relatively low, which may have been due to our limited sample size or the young age of the infants in the present study. In future studies, researchers should examine whether cardiac vagal regulation moderates the relation between infant regulatory capacity and later problem behaviors in more diverse and larger samples using analytical approaches that model dynamic changes in RSA.

Conclusion

Using a longitudinal approach, we found that the relation between infant regulatory capacity at 8 months and behavior problems at 14 months may depend on individual differences in infants' physiological, state-regulated regulation. More specifically, infant regulatory capacity was negatively related to later behavior problems only when infants displayed relatively high cardiac vagal regulation from play to still-face. In the absence of external regulation, effective physiological regulation may reflect adaptive emotion regulation and flexible responding to environmental challenges during infancy and may be related to fewer behavior problems later for infants who display high regulatory capacity.

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Table 1.1

Pearson's Correlations and Descriptive Statistics for Study Variables

Variables	2	3	4	Mean (*SD*)	Range	Skew	Kurtosis
1. Infant regulatory capacity (8 months)	.14	.15	-.05	5.08 (0.67)	3.83 to 6.30	-0.04	-0.58
2. Infant baseline play RSA (8 months)	-	.26†	-.12	3.61 (0.86)	1.50 to 6.10	-0.04	1.41
3. Cardiac vagal regulation (8 months)	-	-	.11	0.06 (0.68)	-1.30 to 2.01	0.23	0.58
4. Behavior problems (14 months)	-	-	-	7.17 (2.89)	2.00 to 14.00	0.59	0.15

†$p < .10$, RSA = respiratory sinus arrythmia, *SD* = standard deviation

Note: Cardiac vagal regulation reflects the change in RSA from the play phase to still-face phase

Table 1.2

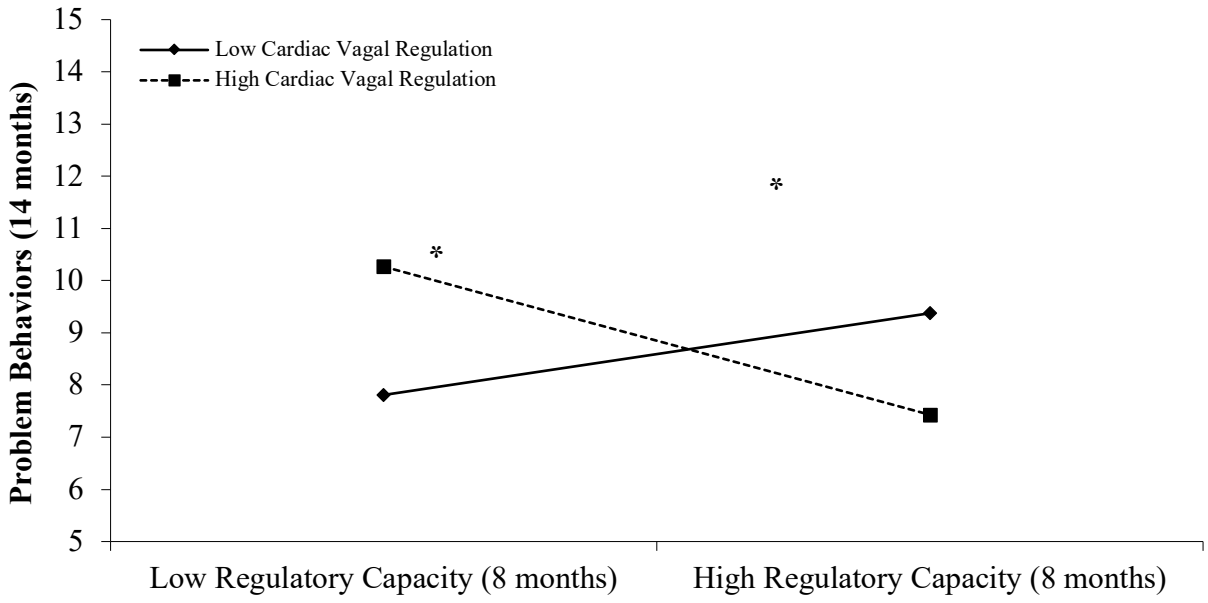
Interaction between Regulatory Capacity and Cardiac Vagal Regulation at 8 Months in Predicting Behavior Problems at 14 Months, Controlling for Play Baseline Respiratory Sinus Arrythmia (RSA)

	Behavior Problems (14 months)			
Predictor	Beta	*SE*	*p*	95% CI
Play baseline RSA (8 months)	-0.38	0.48	.431	-1.35 to 0.59
Regulatory capacity (8 months)	-0.15	0.60	.801	-2.75 to 16.29
Cardiac vagal regulation (8 months)	14.61	5.23	.008	4.08 to 25.15
Regulatory capacity * cardiac vagal regulation	-2.87	1.07	.010	-5.03 to -0.71

CI = confidence interval, RSA = respiratory sinus arrythmia, *SE* = standard error

Figure 1.1

Influence of Regulatory Capacity and Cardiac Vagal Regulation from Baseline Play to Still-Face at 8 Months on Behavior Problems at 14 Months. Asterisk denotes significant slope.



CHAPTER 3

Study 2: Inhibitory control, dyadic social behavior, and mental health difficulties in preschoolers

Hassan, R. & Schmidt, L.A. (2021). Inhibitory control, dyadic social behavior, and mental health difficulties in preschoolers. *Child Development*. Advanced online publication. https://doi.org/10.1111/cdev.13725

Abstract

Although inhibitory control is typically associated with positive outcomes, several theoretical frameworks suggest that too little *and* too much inhibitory control may be problematic. Using a longitudinal, latent variable approach, we examined whether a multi-method index of inhibitory control at Time 1 (N = 105, 52 girls, M_{age} = 3.50 years, 87% White) predicted observed social behavior with an un- familiar peer and maternal report of preschoolers' mental health difficulties at Time 2 (M_{age} = 4.76 years). Data collection occurred between 2017 and 2019. Inhibitory control displayed a U-shaped relation with prospective outcomes, where high *and* low levels of inhibitory control were associated with higher levels of avoidant social behaviors and mental health difficulties. The results are discussed in the context of under- and over-regulation in understanding individual differences in children's social behavior and mental health difficulties.

Introduction

Inhibitory control refers to one's ability to inhibit a prepotent, easily accessible response in favor of activating a less dominant, less accessible response, and is a key component of temperamental effortful control during the preschool period (Rothbart et al., 2001, 2003; Rothbart & Bates, 2006). The typical developmental trajectory of inhibitory control and related constructs, like effortful control, is non-linear, and follows a steep increase from late toddlerhood to the early preschool years, and then levels off, exhibiting a less steep increase from the late preschool to early childhood years (Dennis et al., 2007; Geeraerts et al., 2021; Klenberg et al., 2001; Kochanska et al., 1996; Schoemaker et al., 2014; Williams et al., 1999). Given the importance of the preschool period for the development of inhibitory control, it is particularly important to study the correlates and consequences of inhibitory control during this time.

Most often, inhibitory control is regarded as a positive temperamental quality that is associated with more adaptive socioemotional and psychological outcomes that have important implications for children's ability to secure and maintain healthy social relationships. Indeed, inhibitory control and related constructs have been positively linked to social competence (Di Norcia et al., 2015; Rhoades et al., 2009), prosocial tendencies (Diener & Kim, 2004; Eisenberg et al., 1995, 1997; 2007; Rothbart et al., 2001), the emergence of consciousness and some self-conscious emotions (Eisenberg, 2010; Kochanska & Aksan, 2006), and fewer experiences of aggression (Di Norcia et al., 2015) and mental health difficulties (Eisenberg et al., 2009; Krueger et al., 1996; Olson et al., 2005; Petitclerc et al., 2015; Rapport et al., 1986; Rhoades et al., 2009; B. A. White et al., 2013).

Although inhibitory control is typically regarded as a positive quality, several theoretical models have suggested a U-shaped relation may exist between inhibitory control and

socioemotional and psychological outcomes. The construct of ego control, for example, refers to one's ability to modulate impulses, emotions, and desires in response to dynamic environmental demands (J. Block, 2002; J. H. Block & Block, 1980). Within Block and Block's (1980) framework, ego overcontrol and ego undercontrol represent two extremes, and there is a distinction between adaptive and non-adaptive inhibitory control (Funder & Block, 1989). High ego overcontrol is defined as excessive inhibition of behavior, impulses, emotions, and desires leading to unnecessary denial of pleasure, and a constrained behavioral presentation, whereas high ego undercontrol is defined as inability to delay gratification, emotional lability, impulsivity, and a socially inappropriate behavioral presentation (J. Block, 2002; J. H. Block & Block, 1980; Funder & Block, 1989; Henderson et al., 2015).

Eisenberg and Fabes (1992) have described undercontrolled and highly inhibited children in a similar vein to Block and Block (1980). For example, undercontrolled children exhibit high levels of emotionality, low levels of regulation, and high levels of impulsivity and aggression. Highly inhibited children exhibit high levels of regulation but low flexibility and may be prone to higher levels of anxiety and depression. Here, undercontrolled children are comparable to children with low levels of ego control, and highly inhibited children are comparable to children with high levels of ego control (J. H. Block & Block, 1980; Eisenberg & Fabes, 1992).

Derryberry and Rothbart similarly have discussed the negative influence of both underregulation and overregulation in the context of children's psychopathology more specifically (Derryberry & Rothbart, 1997). Because inhibitory control in each of these frameworks appears to have negative social and psychological consequences at low and high levels, inhibitory control should presumably display a U-shaped relation to socioemotional and

psychological outcomes, with most optimal outcomes exhibited by individuals who display moderate levels of inhibitory control.

Several empirical studies have provided support for the theoretical frameworks suggesting that intermediate levels of inhibitory control may be associated with the most optimal outcomes (J. H. Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992). Two questionnaire-based studies using the concept of ego control found that undercontrolled boys exhibited academic, behavioral, and emotional problems, whereas overcontrolled boys exhibited internalizing problems (Robins et al., 1996), and that intermediate levels of reactive control in preschoolers, a measure of self-regulation conceptually related to ego control, were related to the highest levels of prospective resiliency in a high-risk adolescence sample (Martel et al., 2007). The relation between inhibitory control and resiliency was extended in another study that found intermediate levels of impulsivity were related to the highest resiliency in 4- and 8-year-old children concurrently (Eisenberg et al., 2002).

Beyond questionnaire-measures of self-regulation, two studies using behavioral composites of effortful control in young children found that intermediate levels of effortful control were related to the lowest levels of internalizing and externalizing difficulties (Murray & Kochanska, 2002) and that the modulation of negative affect was also most effective when children displayed intermediate levels of inhibitory control (Carlson & Wang, 2007). Collectively, these studies suggest the relation between inhibitory control and socioemotional and psychological difficulties may be U-shaped rather than linear and positive.

Despite the theoretical perspectives (J. H. Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992) and empirical studies (Carlson & Wang, 2007; Eisenberg et al., 2002; Martel et al., 2007; Murray & Kochanska, 2002; Robins et al., 1996) suggesting a U-

shaped relation between inhibitory control and socioemotional and psychological outcomes, there are several gaps in the literature. First, although previous theoretical models have discussed the potential for negative social consequences of very low and high levels of inhibitory control because of the behavioral consequences of overcontrol (i.e., excessively restricted emotional and behavioral presentation) and undercontrol (i.e., impulsivity, emotional lability, socially inappropriate behavioral presentation (J. Block, 2002; J. H. Block & Block, 1980; Funder & Block, 1989; Henderson et al., 2015; Henderson & Wilson, 2017; Rothbart et al., 1992), to our knowledge, no study has examined whether there is indeed a U-shaped relation between inhibitory control and observed social behavior with a peer.

The lack of considering the peer context is an important gap in the extant literature that should be addressed for at least three reasons. First, it is important to include direct observation of social behavior whenever possible because parental reports of social behavior may not align with how children truly behave with their peers. Parents do not always have opportunities to unobtrusively observe their children's behavior, for example, on the playground. Further, friendships and peer acceptance are protective against psychopathology across childhood (M. E. Schmidt & Bagwell, 2007; Schwartz et al., 2000; Sette et al., 2017), and so it is important to determine factors that influence children's ability to secure positive social relationships with their peers.

A second important gap is that most of the studies considering a non-linear relation have focused on impulsivity (Eisenberg et al., 2002), over- and under-control (Martel et al., 2007; Robins et al., 1996), and effortful control (Murray & Kochanska, 2002). These are important starting points, but theoretical accounts of the potentially negative impacts of "too much" self-regulation focus on descriptions depicting inhibitory control specifically (J. H. Block & Block,

1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992). Further, other studies have suggested that different components of effort control (i.e., inhibitory control, attentional focusing, attentional shifting) may be differentially related to social adjustment (Eggum-Wilkens et al., 2016; L. K. White et al., 2011), highlighting the importance of examining inhibitory control specifically.

A third important gap is the multifaceted nature of inhibitory control. Indices of inhibitory control vary from parent report (Rothbart et al., 2001), coded behavioral observation (Goldsmith et al., 1993; Kochanska et al., 1996, 2000), and cognitive indices (Zelazo et al., 2013). Although different studies have used parent report (Hassan et al., 2020; Sette et al., 2018), cognitive indices (Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011), and behavioral composites (Brooker et al., 2016; Carlson & Wang, 2007; Murray & Kochanska, 2002) when examining the correlates of inhibitory control, the multifaceted nature of inhibitory control calls for a latent factor approach. Latent variable approaches are advantageous because they capture an unobserved variable encompassing the different loadings of various observed variables while accounting for measurement error, potentially creating a more accurate picture of a variable (Kline, 2015).

The Present Study

Given the gaps in the extant literature, the present study used a sample of 105 typically developing preschoolers to examine whether inhibitory control at age 3 (Time 1, T1) influenced observed social behavior with an unfamiliar peer and maternal report of child internalizing and externalizing difficulties approximately one year later (Time 2, T2). We controlled for sex (Hassan et al., 2019; Kochanska et al., 2000; Kochanska & Knaack, 2003), household income (Essex et al., 2006; Lawson et al., 2018), and fearful temperament (i.e., shyness) (Aksan &

Kochanska, 2004; Eggum et al., 2012; Poole et al., 2020) at T1 because of potential links between each of these covariates and inhibitory control, social behavior, and mental health difficulties. We used a latent variable approach to define inhibitory control and social behavior because of the multifaceted nature of each these constructs.

We elected to focus specifically on the preschool period for several reasons. First, the preschool years are a sensitive period for self-regulation development (Dennis et al., 2007; Geeraerts et al., 2021; Klenberg et al., 2001; Kochanska et al., 1996; Schoemaker et al., 2014; Williams et al., 1999). Second, this time reflects a period prior to formal school entry, and social relationships in the early school years are known to be protective against several negative outcomes (M. E. Schmidt & Bagwell, 2007; Schwartz et al., 2000; Sette et al., 2017). Third, mental health difficulties that emerge during the preschool period may persist into preadolescence (Mesman & Koot, 2001). Identifying factors that influence children's social behaviors and internalizing and externalizing problems prior to formal school entry can help identify modifiable targets of intervention that may set children on a positive developmental trajectory.

The present study was considered confirmatory given previous theoretical (J. H. Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992) and empirical work (Carlson & Wang, 2007; Eisenberg et al., 2002; Marcovitch et al., 2010; Martel et al., 2007; Miller et al., 2017; Murray & Kochanska, 2002; Robins et al., 1996). Based on this prior work, we predicted that inhibitory control at age 3 would display a U-shaped relation to negative social outcomes and both internalizing and externalizing problems approximately one year later. Specifically, intermediate levels of inhibitory control would be related to the lowest risk for social and psychological difficulties.

Method

Participants

Participants were 105 typically developing 3-year-old children (52 girls, M_{age} = 3.50 years, SD_{age} = 0.19 years) and their mothers who were recruited from the Child Database in the Psychology, Neuroscience & Behaviour at McMaster University in Ontario, Canada. This database contains the names and contact information of parents of healthy, full-term newborn infants recruited from hospitals across the greater Hamilton metropolitan area who consented to participation in future infant and child studies conducted at McMaster University. Most of the children were White (87%), and their families had a mean household income of between $75,000 and $100,000 in Canadian dollars. Data collection occurred between 2017 and 2019.

Procedure

The present study was part of a larger study examining the influence of temperament on children's prospective social and emotional outcomes across the preschool period. Children and their mothers visited the Child Emotion Laboratory at McMaster University at T1 when the children were three years old. At T1, the child, mother, and one female experimenter began in a room together. While the child played with a puzzle, the experimenter explained the study procedures to the mother. Once the child was acclimated to the laboratory room, the mother went into a separate room in the laboratory to complete a series of questionnaires. She could view her child on a closed-circuit computer monitor in the separate laboratory room. The child completed a Flanker Task on an iPad from the NIH Toolbox Cognitive Battery for preschool-aged children (Zelazo et al., 2013) followed by a dinky toys task (Goldsmith et al., 1993).

Mothers and their children returned to the laboratory for a second time approximately one year later at T2 where the child was paired with another same-sex and same age unfamiliar child

who had also participated in the T1 visit (M_{age} at T2 = 4.76 years SD_{age} = 0.38). The dyad met for the first time in the playroom and proceeded to engage in play activities. The mother was present for the first portion of the play activities, then left the room to complete a series of questionnaires. As with T1, the mother could view the child on a closed-circuit computer monitor while she filled out the questionnaires. All families were provided with small toys, *Junior Scientist* certificates, and $30 gift cards as tokens of appreciation for their participation. Mothers provided written consent and children provided verbal assent for both visits. All procedures were approved by the McMaster Research Ethics Board.

Measures

Inhibitory Control (T1)

A latent factor of inhibitory control included maternal report, coded behavior from the dinky toys task, and cognitive performance on the Flanker Task. Details for the confirmatory factor analysis supporting the latent factor of inhibitory control are described in the Results section.

Maternal Report. Mothers completed the Children's Behavior Questionnaire (CBQ), which is a parent-rated questionnaire evaluating 3- to 7-year-old children's temperament (Rothbart et al., 2001). Of particular interest to the present study were parental ratings of inhibitory control. On this 14-item scale, parents rate items on a 7-point scale with 1 = *Never* and 7 = *Always*. Mean scores were computed, and thus scores could range from 1 to 7. A sample item from the inhibitory control scale is "Can wait before entering into new activities if s/he is asked to", and the scale exhibited strong internal consistency (α = .82).

Dinky Toys Task. This task is a behavioral measure of inhibitory control and is adapted from a previous study (Kochanska et al., 1996) and the Preschool Lab-TAB (Goldsmith et al.,

1993). The experimenter and child were seated cross-legged across from each other on the floor, and the child was presented with a box of attractive dinky toys and asked to indicate using their words which toy they would like while keeping their hands on their lap. The experimenter then slid the box over to the child and reminded the child to keep their hands on their lap before removing the lid of the box. The child then either told the researcher which toy they wanted or grabbed the toy. The experimenter gave the child one more reminder to keep their hands on their lap if a choice was not made within 5 seconds. Following the first choice, the child was told, "Because you did such a good job today, I'm going to let you pick another prize to take home." The procedure was then repeated.

Performance on the dinky toys task was unobtrusively digitally recorded and was subsequently coded. Children's strategy was coded on a 0- to 5-point scale, following the coding scheme of (Kochanska et al., 1996). A 0 was assigned if the child grabbed the toy out of the container; a 1 was assigned if the child touched the toys in the container but did not take a toy out; a score of 2 was given if the child pointed to the toys but did not touch them; a 3 was assigned if the child removed their hands from their lap but did not touch the toy; a 4 was assigned if the child's hands twitched or moved slightly but did not leave the lap; and a 5 was assigned if the child did not move their hands from their lap. Because this task was completed twice and the scores were highly correlated ($r = .73$, $p < .001$), scores for children's strategies were averaged between the two trials. To establish reliability, independent coders overlapped on 18% of the videos, and good interrater reliability was established (κ trial 1 = .95, κ trial 2 = .96).

Flanker Task. The Flanker Task from the NIH Toolbox Cognitive Function Battery was used to measure cognitive inhibitory control which was administered using an iPad (Zelazo et al., 2013). During this task, the child was first presented with a row of fish and was instructed to

press the button that matched the direction that the middle fish was pointing. This task consisted of congruent trials where all the fish were facing the same direction and incongruent trials where all the fish were facing the opposite direction from the middle fish. If the child performed above a certain cut-off point, they completed a second version of this task where they saw arrows instead of fish. The Flanker Task consisted of 4 practice trials, 20 trials using fish as stimuli, and 20 trials using arrows as stimuli. Detailed information on how scoring is computed is described elsewhere (Zelazo et al., 2013). Each child was given a percentile based on their standardized, age-corrected score.

Fearful Temperament (T1)

CBQ. The 6-item shyness subscale from the CBQ was used as an index of fearful temperament at T1 (Rothbart et al., 2001). Statements were rated by mothers on a scale ranging from 1 (never) to 7 (always). A sample item from the shyness scale includes "Acts shy around new people". The shyness ($\alpha = .89$) scale demonstrated good internal consistency.

Observed Dyadic Social Behavior (T2)

Children's social behavior was observed in a free play context with an unfamiliar peer separately with and without the mothers present. A latent factor of avoidant social behaviors included displays of *negative affect* in the free play session with the mothers present and a separate free play session without the mothers, and *unoccupied/onlooking behaviors* during the freeplay session without the mothers present. We focused specifically on negative affect and unoccupied and onlooking behaviors because these social behaviors can be a result of internal (e.g., fear) and external (e.g., peer rejection) triggers, and presumably would capture a dynamic picture of negative social experiences. Details for the confirmatory factor analyses supporting the latent factor of avoidant social behaviors is described in the Results section.

Observed Dyadic Social Behavior. One member of the dyad pair was in the laboratory playroom with their mother. The second member of the dyad pair was brought into the laboratory playroom with their mother by a female research assistant, and the female research assistant introduced the two unfamiliar children for the first time. Following the introduction, the research assistant immediately brought in a large plastic bin filled with different toys (e.g., puzzles, blocks, dolls, cars) into the playroom and told the children they had 10 minutes to play with the toys in the bin together, and then she left the room. The mothers sat in the corner of the room on two chairs and completed questionnaires on a clipboard using a pen and paper. After 10 minutes, the research assistant returned to the room and told the children it was time for their next activity.

Children's social behavior was unobtrusively digitally recorded and was subsequently coded by independent research assistants, and behavioral codes were heavily adapted from the Play Observation Scale (see Rubin, 2001). Children's negative affect and unoccupied/onlooking behaviors were coded every 10 seconds. Negative affect in both the free play session with and without the mothers was based on facial (e.g., pouting lips, frowning), verbal (e.g., crying, whining), and behavioral displays (e.g., hanging head, slacked posture) on a scale of 1 (none displayed) to 4 (continued mild or stronger expression >7 seconds; two or more distinct, strong expressions; four or more distinct, mild-to-moderate expressions).

Unoccupied/onlooking behavior was operationalized as the child staring blankly into space or wandering around with no specific purpose and was coded when it was displayed the most out of several other mutually exclusive play behaviors derived from the Play Observation Scale (Rubin, 2001). Although this behavior was coded in the free play sessions both with and without the mothers present, the instance was very low when the mothers were present. As such, we focused only on unoccupied/onlooking behavior in the free play session without the mothers

present. Because of small delays (e.g., 15 seconds) in ending the play episode, proportion scores were used where the sum of each behavior was divided by the number of minutes the play episode lasted. Negative affect with (κ = .87) and without the mother (κ = .84) and unoccupied/ onlooking without the mother (κ = .86) exhibited acceptable to excellent interrater reliability.

Mental Health Difficulties (T2)

Child Behavior Checklist. Mothers completed the Child Behavior Checklist (CBCL), which is a parent-rated questionnaire evaluating emotional and behaviors in children ages 1.5 to 8 years old (Achenbach & Edelbrock, 1978; Achenbach & Rescorla, 2000). Of particular interest to the present study were maternal ratings of internalizing and externalizing problems. Parents rate items on a 3-point scale with 0 = *Not true (as far as you know)* and 2 = *Very true or often true*. Mean scores were computed, and thus scores could range from 0 to 2. A sample item from internalizing scale includes "Looks unhappy without a good reason" and a sample item from the externalizing scale includes "screams a lot". The internalizing (α = .79) and externalizing (α = .93) difficulties scales exhibited good and excellent internal consistency, respectively.

Missing Data and Loss to Follow Up

Of the 105 children at T1, 18 were missing Flanker data due to either not passing the teaching trials (n = 16) or refusal to participant or finish the task (n = 2), 3 were missing data on the dinky toys due to experimenter error (n = 1) or refusal to participate (n = 2), and 2 were missing maternal report of inhibitory control data due to refusal to participate (n = 2). Because children overlapped on missing data, 87 children had complete data at T1.

This present study was part of a larger study examining the influence of temperament on prospective social relationships in preschool children and included both a dyadic and individual visit at T2. The variables of interest in the present study occurred during the dyadic portion of

T2. Because it was difficult to align schedules of families with children of the same-sex for the dyadic portion, 62 children returned for their T2 dyad visit. Two children at T2 were matched with a same-sex, same age child who had not been tested at the T1 visit because we were unable to align the schedules of these two children with any of the children tested at T1, and so a total of 64 children had T2 dyad data. The retention rate for children who returned to complete an individual visit at T2 rather than the dyadic portion at T2 was $n = 71$.

The children who did not complete the T2 dyadic portion did not differ from those children who did based on age ($t(102) = -0.48$, $p = .63$), sex ($X^2 (1, N = 105) = 1.01$, $p = .31$), household income ($t(97) = -1.08$, $p = .28$), Flanker percentile ($t(85) = -0.16$, $p = .87$), dinky toys coded behavior ($t(100) = -0.51$, $p = .61$), maternal report of inhibitory control ($t(101) = -0.63$, $p = .53$), or maternal report of fearful temperament ($t(101) = 0.59$, $p = .56$).

Little's test of Missing Completely at Random (MCAR) was not significant, $\chi2 = 164.36$, $df = 509$, $p = 1.00$, suggesting that patterns of missing data did not violate the assumption that data were missing completely at random. To leverage the complete sample ($N = 105$) and avoid the biased parameter estimates that can occur with pairwise or listwise deletion (Schafer & Graham, 2002), children who did not return for the second visit were given a dyad pairing value based on same-sex matching and the date of their T1 visit, and then missing data were imputed using the expectation-maximization algorithm.

Statistical Analyses

To derive latent factors of inhibitory control and observed social behaviors, we performed two confirmatory factor analyses (CFA) in Mplus Version 8 using an MLR estimator. To account for the nested nature of the observed dyadic social behaviors where behaviors are nested within the child, and the child is nested within the dyad, we used the TYPE = COMPLEX

function. This specification allowed us to control for the effect of the dyad (Huang, 2018). The cluster variable in our analyses was dyadic pairing. After specifying the measurement models for the latent factors, we built two structural equation models (SEM) that included the linear and quadratic influence of inhibitory control on either observed social behavior or mental health difficulties at T2 controlling for sex, household income at T1, and fearful temperament (i.e., shyness) at T1. Estimates are also provided without the covariates for completeness. Imputation was conducted in SPSS version 26, and the main analyses were conducted in MPlus Version 8.

Results

Table 2.1 includes the means, standard deviations, and intercorrelations among all observed variables.

Measurement Models

Inhibitory Control (T1). Figure 2.1A depicts the latent factor of inhibitory control supported by a CFA. T1 maternal ratings of inhibitory control, coded observations of children's behavior during the dinky toys task, and percentile scores from the Flanker Task were used as indicators of inhibitory control. To improve model fit, we constrained the three inhibitory control indicators to be equal. In order to justify the constrained model, we performed a Satorra-Bentler Scaled Chi Square difference test (Satorra & Bentler, 2001). This test is used to compare the fit of different models when an MLR estimator is used. We obtained a non-significant chi-square statistic, $X^2 = .11$, $df = 2$, $p = .948$, and so we retained the more parsimonious constrained model with more degrees of freedom. The first factor was freed, and the latent factor was set to 1. The CFA for inhibitory control demonstrated acceptable fit (root mean square error of approximation [RMSEA] = 0, comparative fit index [CFI] = 1, standardized root mean square residual [SRMR] = .010), where Flanker percentile ($\beta = 0.49$, $SE = 0.11$, $p < .001$), dinky toys behavior ($\beta = 0.43$,

SE = 0.12, $p < .001$), and maternal ratings of inhibitory control (β = 0.45, *SE* = 0.13, $p = .001$) all loaded significantly onto the latent factor.

Social Behavior (T2). Figure 2.1B depicts the latent factor of avoidant social behavior supported by a CFA. T2 scores of negative affect during free play with and without the mothers present and unoccupied/onlooking behaviors during free play without the mothers were used as indicators of avoidant social behavior. To improve model fit, we constrained negative affect and unoccupied/onlooking behaviors without the mothers present to be equal. To justify the constrained model, we performed another Satorra-Bentler Scaled Chi Square difference test (Satorra & Bentler, 2001). We obtained a non-significant chi-square statistic, $X^2 = .18$, $df = 1$, $p = .665$, and so we retained the more parsimonious constrained model with more degrees of freedom. The first factor was freed, and the latent factor was set to 1. The CFA for avoidant social behavior demonstrated acceptable fit (RMSEA = 0, CFI = 1, SRMR = .008), and negative affect with (β = 0.42, *SE* = 0.09, $p < .001$) and without mothers present (β = 0.62, *SE* = 0.12, $p < .001$), and unoccupied/onlooking behaviors (β = 0.15, *SE* = 0.04, $p < .001$) all loaded significantly onto the latent factor.

Influence of Inhibitory Control on Prospective Social Behavior and Mental Health Difficulties

Observed Avoidant Social Behavior. The SEM included the linear and quadratic effects of the latent variable inhibitory control on the latent variable avoidant social behavior, controlling for sex, T1 household income, and T1 shyness (Akaike information criterion = 1143.07, Bayesian information criteria [BIC] = 1193.35, sample size adjusted BIC = 1139.64). Both the linear (β = 0.65, *SE* = 0.34, $p = .05$) and quadratic (β = 2.52, *SE* = 1.12, $p = .02$) effects of inhibitory control were significantly related to prospective avoidant social behavior. Because

the interaction (i.e., quadratic relation) is prioritized over the main effect (i.e., linear relation), we focused on interpreting the quadratic relation. Figure 2.2 visually depicts the nature of the U-shaped relation, and Figure 2.3 depicts the regions of significance. Consistent with our predictions, the relation between inhibitory control and avoidant social behavior during the dyadic interaction involving an unfamiliar peer was positive at both high and low levels of inhibitory control.

The model provided similar estimates when covariates were removed (Akaike information criterion = 1151.31, Bayesian information criteria [BIC] = 1196.75, sample size adjusted BIC = 1143.03), where both the linear (β = 0.74, *SE* = 0.26, *p* = .004) and quadratic (β = 2.07, *SE* = 0.26, *p* = .004) influence of inhibitory control were significantly related to prospective avoidant social behavior. The pattern of results also remained unchanged when we replaced the latent factor of observed social behavior with its individual indicators.

Internalizing Difficulties. The second SEM included the linear and quadratic effects of the latent variable inhibitory control on internalizing difficulties, controlling for sex, T1 household income, and T1 shyness (Akaike information criterion = 769.02, Bayesian information criteria [BIC] = 806.32, sample size adjusted BIC = 762.08). The linear estimate of inhibitory control was nonsignificantly related to internalizing difficulties (β = 0.02, *SE* = 0.02, *p* = .201) However, the quadratic (β = 0.08 *SE* = 0.01, *p* < .001) effect of inhibitory control was significantly related to prospective internalizing difficulties. Figure 2.4A visually depicts the nature of the U-shaped relation, and Figure 2.5A depicts the regions of significance. Consistent with our predictions, the relation between inhibitory control and internalizing difficulties was positive at both high and low levels of inhibitory control.

The model provided similar estimates when covariates were removed (Akaike information criterion = 790.49, Bayesian information criteria [BIC] = 819.89, sample size adjusted BIC = 785.14), where the linear estimate of inhibitory control was not significantly related to internalizing difficulties (β = 0.02, *SE* = 0.03, *p* = .489), but the quadratic influence of inhibitory control was significantly related to internalizing difficulties (β = 0.06 *SE* = 0.01, *p* < .001).

Externalizing Difficulties. The third SEM included the linear and quadratic effects of the latent variable inhibitory control on externalizing difficulties, controlling for sex, T1 household income, and T1 shyness (Akaike information criterion = 898.76, Bayesian information criteria [BIC] = 936.05, sample size adjusted BIC = 891.92). Both the linear (β = -0.15, *SE* = 0.38, *p* < .001) and quadratic (β = 0.09 *SE* = 0.02, *p* < .001) effects of inhibitory control were significantly related to prospective externalizing difficulties. Because the interaction (i.e., quadratic relation) is prioritized over the main effect (i.e., linear relation), we focused on interpreting the quadratic relation. Figure 2.4B visually depicts the nature of the quadratic relation, and Figure 2.5B depicts the regions of significance. Consistent with our predictions, the relation between inhibitory control and externalizing problems was positive at both high and low levels of inhibitory control.

The model provided similar estimates when covariates were removed (Akaike information criterion = 902.58, Bayesian information criteria [BIC] = 931.99, sample size adjusted BIC = 897.23), where both the linear (β = -0.15, *SE* = 0.04, *p* < .001) and quadratic (β = 0.09 *SE* = 0.02, *p* < .001) influence of inhibitory control were significantly related to prospective externalizing difficulties.

Discussion

Using a longitudinal, multi-method approach, we examined whether inhibitory control displayed a U-shaped relation with prospective social behaviors same-sex dyads and psychological difficulties as suggested by several theoretical frameworks (J. H. Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992; Henderson et al., 2015). We found that age 3 inhibitory control displayed a U-shaped relation with age 4 outcomes, where children with low and high inhibitory control had relatively higher levels of avoidant social behavior and mental health difficulties.

The results from the present study were in line with theoretical frameworks which have suggested both over and underregulation can have negative consequences for children (J. Block, 2002; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992). These frameworks suggest that underregulation can be disadvantageous for children's social and psychological development because it can lead to impulsivity, emotionally lability, and socially inappropriate behavior. Overregulation, on the other hand, may also be disadvantageous because it may lead to excessive and unnecessary inhibition of impulses and desires, behavioral rigidity, and limited flexibility. The results from the present study support these theoretical assertions with empirical evidence, suggesting the U-shaped relation between inhibitory control and psychosocial difficulties was present across the preschool period in the context of inhibitory control, avoidant social behavior with an unfamiliar peer, and maternally reported psychological difficulties.

One notable strength of the present study was the inclusion of a free play session with an unfamiliar peer used to elicit social behaviors. To our knowledge, no study has examined the curvilinear influence of inhibitory control on observed social behaviors in the peer context. Children with intermediate levels of inhibitory control appeared to engage in less prospective avoidant social behavior with an unfamiliar peer. We speculate low and high levels of inhibitory

control prevent children from flexibility engaging in social interactions with their peers, potentially because of over and under control. These results have important psychosocial implications for children. While avoidant behaviors in and of themselves do not represent psychopathology, high levels of negative affect and unoccupied and onlooking behaviors have indeed been associated with more negative outcomes. For example, some studies have found associations between reticent play behaviors and higher internalizing difficulties (Degnan et al., 2014), negative emotionality (Coplan & Rubin, 2001), lower peer ratings of group acceptance (Hart et al., 2000), and social competence (Coplan et al., 2001). Children's ability to engage in positive social interactions contributes to the development of friendships (Rubin et al., 1995), and friendships are an important protective factor for children's psychological adjustment (M. E. Schmidt & Bagwell, 2007; Schwartz et al., 2000; Sette et al., 2017). Together, these studies highlight the importance of identifying factors contributing to children's engagement with a peer.

Children with intermediate levels of inhibitory control had lower prospective maternal ratings of internalizing and externalizing difficulties relative to children with low and high levels of inhibitory control. Like the relation between inhibitory control and avoidant social behaviors in the present study, the flexibility associated with intermediate inhibitory control may make children more resilient against developing mental health difficulties. Our results are particularly important considering the developmental period under investigation. Although some preschoolers' emotional and behavioral problems are transient, others are relatively stable or increase the risk for future internalizing and externalizing problems (Campbell & Ewing, 1990; Egeland et al., 1996; Fischer et al., 1984; Lavigne et al., 1998; Mesman & Koot, 2001; Rose et al., 1989), highlighting the importance of identifying early predictors of mental health difficulties in preschoolers.

An additional contribution of the present study was a multi-method, latent variable approach to self-regulation. We used behavioral, cognitive, and parent-reported indicators of inhibitory control, which we believe more accurately captures the multifaceted nature of inhibitory control than any one indicator alone. Although there is value in each of these measures independently, using multiple indicators of a multifaceted construct like inhibitory control allows for a more dynamic conceptualization of inhibitory control, moving beyond a single observation in time, and potentially reducing measurement error (Kline, 2015). Relying on behavioral, cognitive, and parent-reported indicators may, for example, account more effectively for a child who does not perform to his or her potential during the dinky toys task for reasons unrelated to underlying inhibitory control (e.g., disinterest in specific toys, sleepiness).

Strengths, Limitations, and Future Directions

The present study had several strengths. These included a longitudinal design during a developmentally sensitive period for self-regulation (Dennis et al., 2007; Geeraerts et al., 2021; Klenberg et al., 2001; Kochanska et al., 1996; Schoemaker et al., 2014; Williams et al., 1999), the adoption of a latent variable approach to inhibitory control and social behavior, directly observed children's social behavior during dyadic peer interactions, and the examination of linear and non-linear effects.

The present study also had several limitations that warrant discussion. First, the number of participants lost to follow up in the present study was relatively high, which was partially accounted for by the difficulties associated with aligning the schedules of two families with so that their children could be paired in same-sex dyads who had been previously tested at T1. It is important to note, however, that missingness was not associated with any of the T1 variables of interest or sociodemographic information, the patterns of missing data did not violate the

assumption that data were missing completely at random. As well, we used imputation techniques that should theoretically lead to less biased estimates than listwise deletion (Schafer & Graham, 2002).

Another important consideration in the present study was the free play context used to elicit social behaviors. Although the inclusion of two children and free play instructions may have some characteristics in common with how children behave in naturalistic settings, the laboratory context includes some demand characteristics that prevent us from generalizing to how children behave with their peers outside of the laboratory. However, the laboratory also has important benefits over a more naturalistic setting including greater environmental control and protocol standardization.

Related to generalizability, our sample was low risk and from the community, primarily White, and the mean household income was relatively high. Although we controlled for household income as a proxy for socioeconomic status in the present study, because the mean household income was relatively high, it is possible that we simply did not have enough low-income families to fully account for the impact of household income. Consequently, our results might not be generalizable to children from more socioeconomically disadvantaged homes and ethnically diverse backgrounds.

Related to issues of measurement, it is important to note that the raw correlations between different facets of inhibitory control were significant but relatively weak. This is not surprising, because the unique sources of noise unrelated to inhibitory control are likely captured by each measurement modality. For example, scores on the dinky toys task may be influenced by the attractiveness of toys to child; Flanker percentiles may be impacted by the child's sleepiness; and parental reports of inhibitory control may be influenced by the temperament of the target

child's siblings due to comparison parents may make between children. Correlations will be likely be lower across modalities versus within modalities. For example, a correlation between different parental reports of inhibitory control will be likely higher than a correlation between a parent report and behavioral index of inhibitory control, because of the shared noise and measurement error within modalities. We believe the added benefit of using various indices capturing a more fulsome measure of inhibitory control, accounting for measurement error using a latent variable, and excellent model fit outweighs the downside of relatively low correlations between and among the three indicators.

It is also important note that there have been concerns raised recently about the use of a regions of significance test to interpret a curvilinear relation because regions of significance tests may be biased in detecting a U-shaped over a linear relation (Simonsohn, 2018). A two-lines approach has been suggested over a regions of significance test to probe a curvilinear relation (Simonsohn, 2018). To our knowledge, the two lines approach was not possible in the present study given the latent variable approach. As a result, the results of the present study should be interpreted with this limitation in mind.

Although the present study was longitudinal in nature, we also cannot establish temporal precedence because inhibitory control was measured at T1, and social behavior and mental health difficulties were measured at T2. We cannot, therefore, determine that inhibitory control *leads* to avoidant social behaviors and mental health difficulties. It is possible that avoidant social behaviors and mental health difficulties were already present at T1. It is also possible that factors outside of inhibitory control and the scope of the present study may influence avoidant social behavior and mental health difficulties including parenting, temperament, and negative

social experiences. Future work should consider examining repeated measures collected concurrently and prospectively.

Lastly, we used questionnaires to index children's mental health difficulties, which may be subject to more bias than clinical ratings. However, the CBCL is widely used and psychometrically sound (Achenbach & Rescorla, 2000). Within the limits of the present study, we believe the use of maternal report provides important convergent evidence with behavioral observation. Future studies should examine the curvilinear influence of inhibitory control on preschoolers' observed social behavioral and mental health difficulties in a more naturalistic setting such as the playground or school environment, using multiple measures of mental health difficulties, including teacher and child report, in a more socioeconomically and ethnically diverse sample.

Conclusion

We found a curvilinear relation between preschoolers' inhibitory control at age 3 and prospectively observed avoidant social behavior with an unfamiliar same-sex peer and maternal reports of child mental health difficulties approximately at age 4. Children with intermediate levels of inhibitory control displayed relatively lower levels of avoidant social behaviors and mental health difficulties compared to children with relatively higher and lower levels of inhibitory control. The results from the present study support longstanding theoretical perspectives suggesting that over and under regulation may lead to socioemotional and psychological difficulties and have theoretical and practical implications to understanding socioemotional development before formal school entry.

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Table 2.1

Pearson's Correlations and Descriptive Statistics for Study Variables

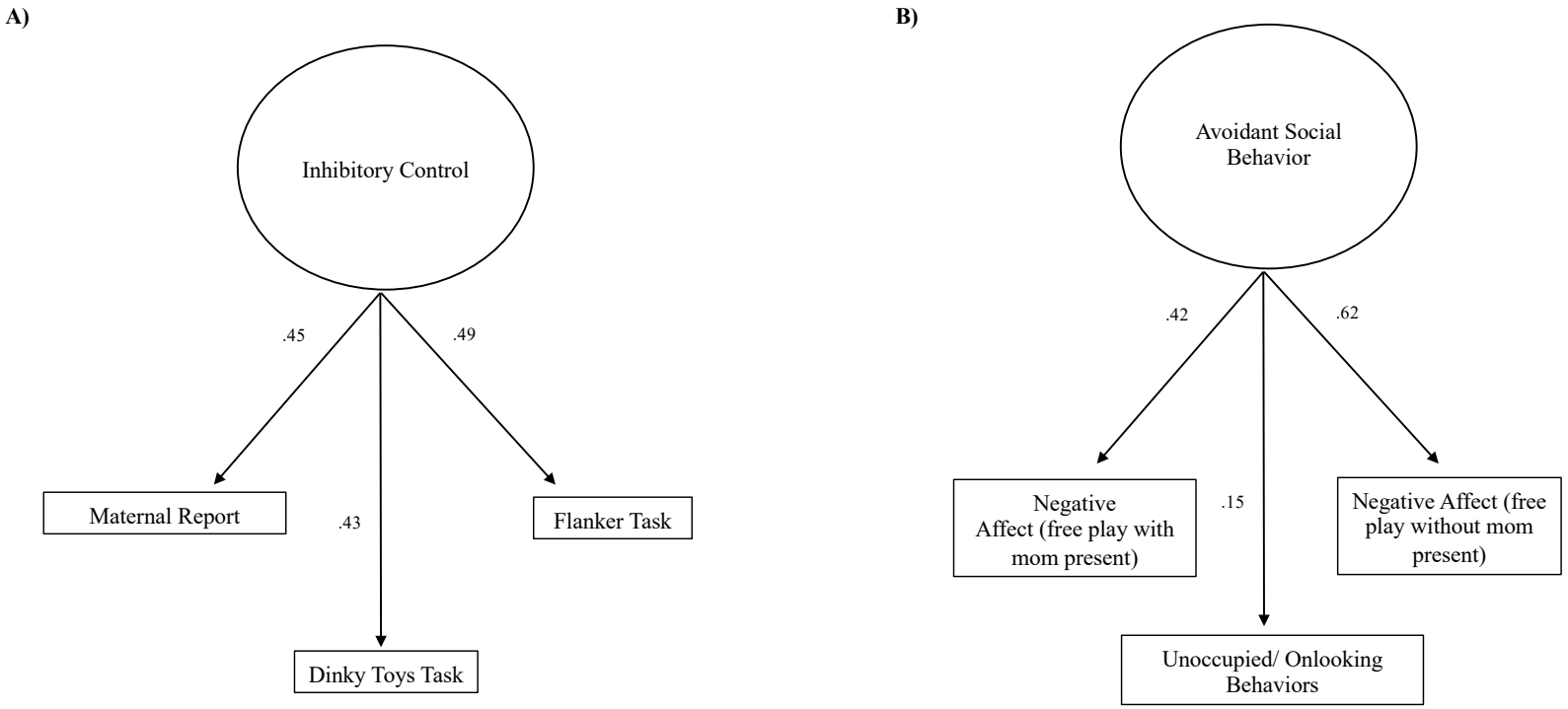
Variables	2	3	4	5	6	7	8	Mean (*SD*)
1. CBQ inhibitory control (T1)	.22*	.22*	.13	.01	-.09	-.09	-.47**	4.71 (0.72)
2. Dinky toys behavior (T1)	-	.20*	.09	.19*	.11	.16†	-.13	1.37 (1.63)
3. Flanker percentile (T1)	-	-	.07	.12	-.06	.08	.11	58.34 (27.03)
4. Negative affect during free play with the mother (T2)	-	-	-	.64***	.44**	.14	.13	6.17 (0.69)
5. Negative affect during free play without the mother (T2)	-	-	-	-	.64***	.13	.11	6.09 (0.65)
6. Unoccupied/onlooking during free play without the mother (T2)	-	-	-	-	-	.16†	.15	0.06 (0.22)
7. Internalizing difficulties (T2)	-	-	-	-	-	-	.48***	0.26 (0.16)
8. Externalizing difficulties (T2)	-	-	-	-	-	-	-	0.36 (0.27)

T1 = Time 1, Age 3; T2 = Time 2, Age 4

† $p < .10$, * $p < .05$, **$p < .01$, ***$p < .001$

Figure 2.1

Confirmatory Factor Analysis Supporting Latent Factors (A) Inhibitory Control at Time 1 (M_{age} = 3.50 years) and (B) Avoidant Social Behavior during Dyadic Free Play and at Time 2 (M_{age} = 4.76 years)



Note. All factor loadings are significant.

Figure 2.2

Quadratic Influence of Latent Inhibitory Control at Time 1 (M_{age} = 3.50 years) on Avoidant Social Behavior during Free Play with an Unfamiliar Same-Sex Peer at Time 2 (M_{age} = 4.76 years)

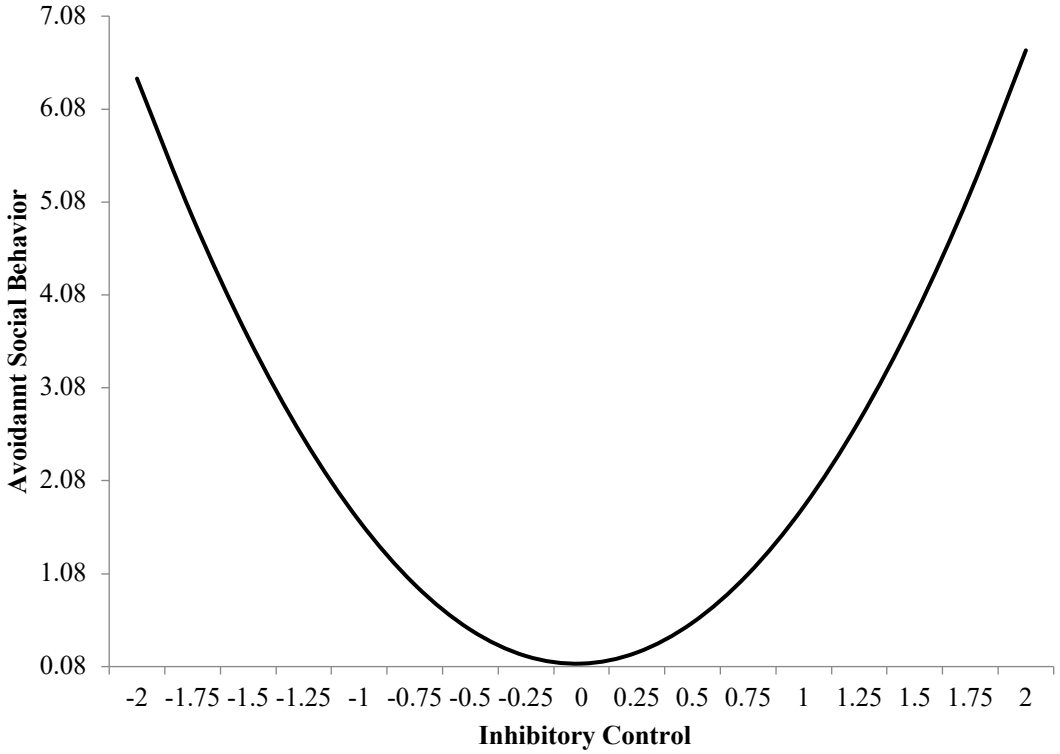


Figure 2.3

Regions of Significance in the Relation between Latent Inhibitory Control at Time 1 (M_{age} = 3.50 years) and Latent Avoidant Social Behavior during Free Play with an Unfamiliar Same-Sex Peer at Time 2 (M_{age} = 4.76 years)

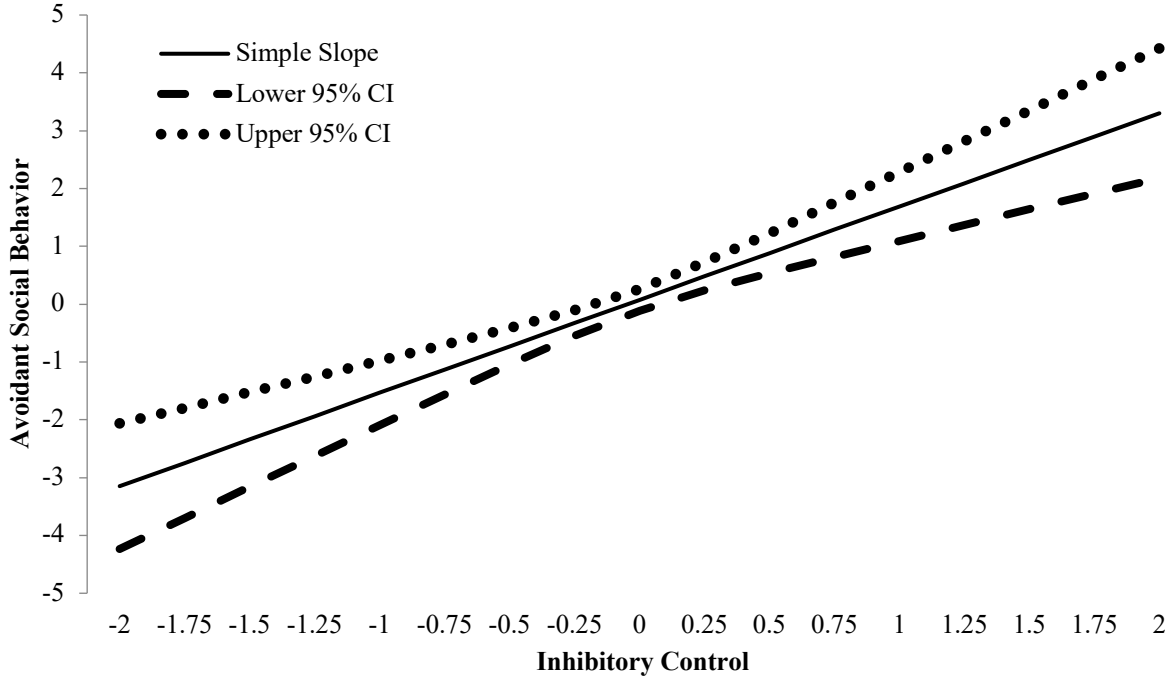
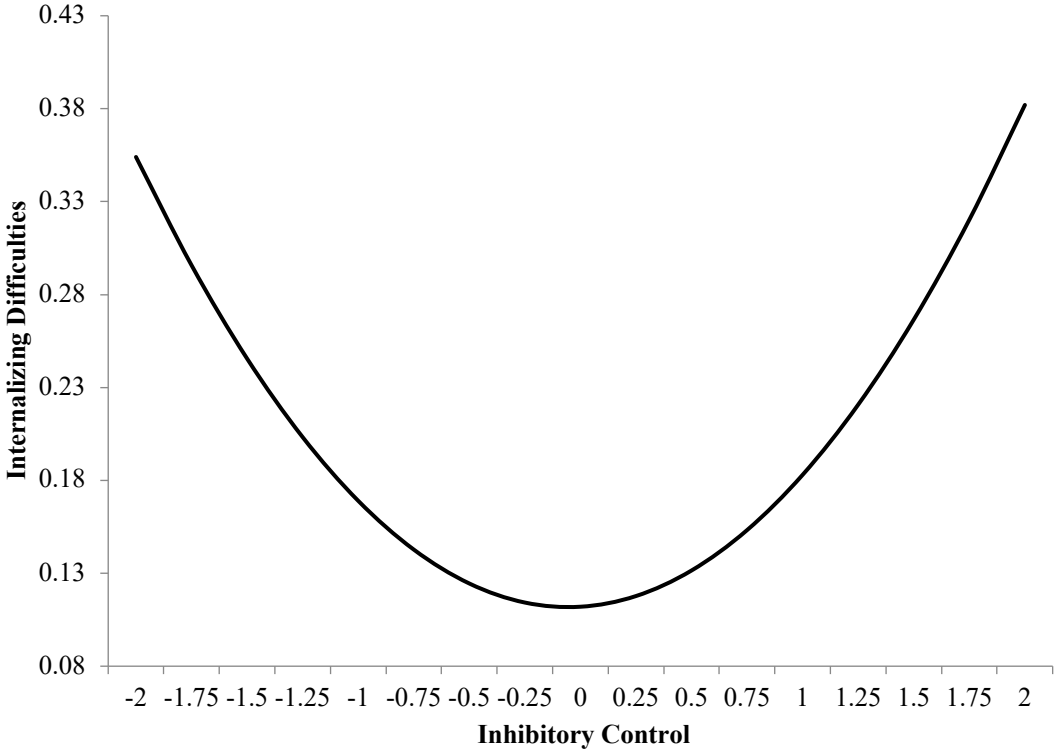
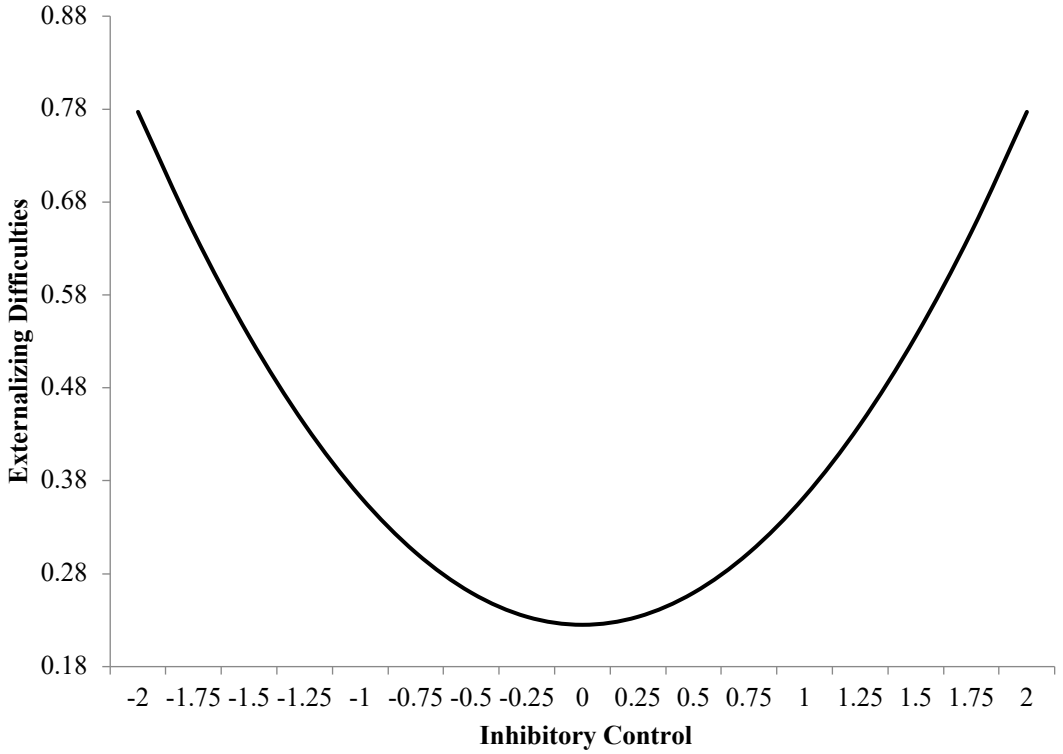


Figure 2.4

Quadratic Influence of Latent Inhibitory Control at Time 1 (M_{age} = 3.50 years) on Internalizing (A) and Externalizing (B) Difficulties at Time 2 (M_{age} = 4.76 years)



A)

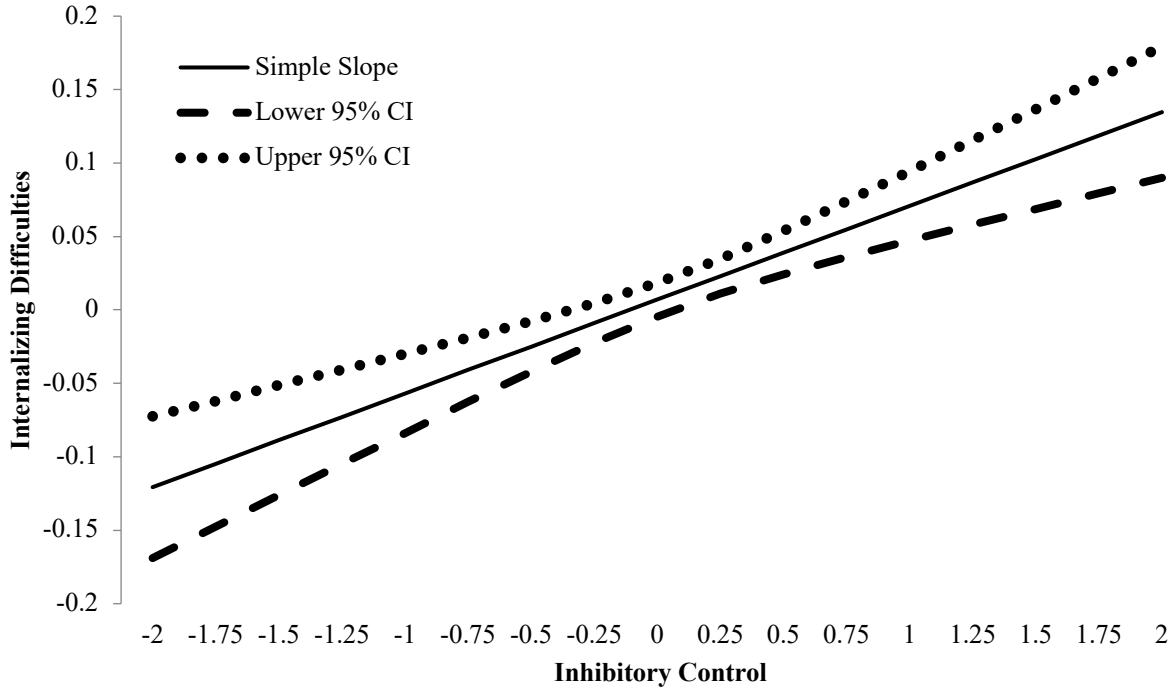

0.88
0.78
0.68
0.58
0.48
0.38
0.28
0.18
Externalizing Difficulties
-2 -1.75 -1.5 -1.25 -1 -0.75 -0.5 -0.25 0 0.25 0.5 0.75 1 1.25 1.5 1.75 2
Inhibitory Control

B)

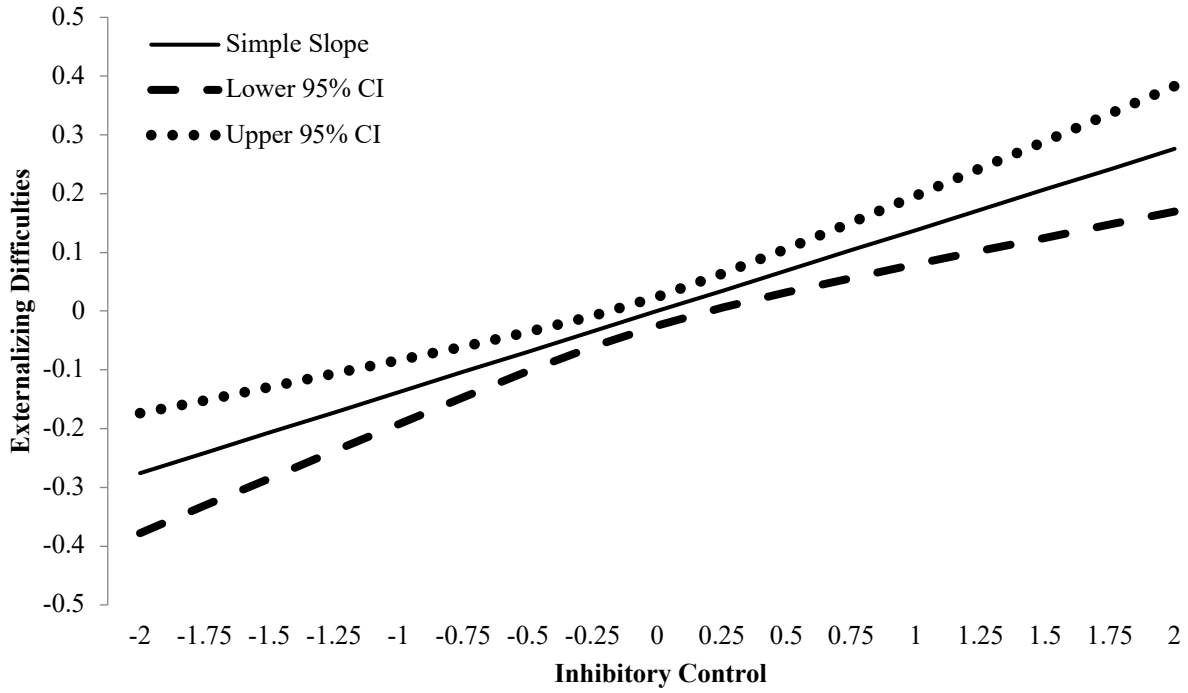
Figure 2.5

Regions of Significance for the Relation between Latent Inhibitory Control at Time 1 (M_{age} = 3.50 years) and Internalizing (A) and Externalizing (B) Difficulties at Time 2 (M_{age} = 4.76 years)

A)



B)
`


Simple Slope
Lower 95% CI
Upper 95% CI
Externalizing Difficulties
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-2
-1.75
-1.5
-1.25
-1
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
Inhibitory Control

CHAPTER 4

Study 3: Shyness and inhibitory control in preschool dyads: An actor partner model of social behavior

Hassan, R. & Schmidt, L.A. (Under Review). Shyness and inhibitory control in preschool dyads: An actor partner model of social behavior. *Manuscript submitted for publication.*

Abstract

The risk potentiation model of cognitive control posits that inhibitory control heightens children's risk for problematic outcomes in the context of shyness because it limits shy children's ability to engage flexibility with their environment. Although previous research has found empirical support for the risk potentiation model, most studies have been restricted to parent report of children's outcomes. In the present study, we used an actor-partner interdependence model to examine whether shyness and a multimethod index of inhibitory control at Time 1 (N = 105, 52 girls, M_{age} = 3.50 years) predicted children's own and their partner's observed social approach and avoidance with an unfamiliar peer at Time 2 (M_{age} = 4.76 years). In line with the risk potentiation model, we found that shyness negatively predicted children's own prospective approach behaviors with a peer only when the child's own inhibitory control was relatively high. We also found that shyness was positively associated with the partner's avoidance behaviors when the child's own inhibitory control was relatively low, and negatively associated with the partner's avoidance behaviors when the child's own inhibitory control was relatively high. Although shyness was negatively associated with the child's own prospective approach when their inhibitory control was high, these relations do not necessarily translate to less approach from the social partner. These results highlight the importance of examining the child's own behavior in addition to their social partner's behavior when considering children's social development.

Introduction

Temperamental shyness refers to a tendency towards fear, inhibition, and avoidance in the face of social novelty (Kagan et al., 1988; Karevold et al., 2012; Sanson, 1996). Perhaps because of the ubiquity of shyness and its negative perceptions (Zimbardo, 1977), several studies have examined the social and interpersonal consequences of shyness across childhood. For example, in the context of a stranger approach task, shyness was associated with a high and steeply increasing trajectory of observed avoidance in preschool-aged children (Hassan & Schmidt, 2021) and displayed a curvilinear relation with gaze, where higher levels of shyness were associated with both low levels of gaze aversion (i.e., attentional vigilance) and high levels of gaze aversion (i.e., attentional avoidance) in 7-to 8-year-old children (Poole & Schmidt, 2021). Shyness has also been positively associated with reticent social behaviors in preschool aged children (Coplan et al., 2001; Hane et al., 2008; Sette et al., 2022). Beyond nonverbal displays of avoidance, shy children also speak less in unfamiliar social situations (Asendorpf & Meier, 1993; Crozier & Perkins, 2002; Evans, 1993). Higher levels of observed avoidance may also manifest in differences in shy children's social relationships. For example, in one study, shyness was positively associated with peer difficulties in school-aged children (Coplan et al., 2008), but another study failed to find a direct relation between shyness and peers' responses during childhood (Fordham & Stevenson-Hinde, 1999). Although these studies suggest shyness is associated with differences in observed social behavior and social relationships, not all shy children go on to develop social difficulties, and so it is important to examine moderating factors that might help explain this heterogeneity in outcomes. Self-regulation may act as one such moderator.

Self-regulation broadly encompasses the affective, behavioral, cognitive, and physiological processes which function to modulate reactivity and support goal-directed behavior (McClelland et al., 2010; Rothbart & Bates, 2006). Typically, self-regulation is conceptualized as a desirable quality in childhood because it is positively associated with more adaptive social, (Eisenberg et al., 2010; Wilson, 2003), academic (Graziano et al., 2007; Ponitz et al., 2009), and psychological (Eisenberg et al., 2009, 2010) adjustment. However, the risk potentiation model of control posits that some components of self-regulation may be maladaptive depending on individual differences in temperament (Henderson et al., 2015; Henderson & Wilson, 2017).

The risk potentiation model of control focuses specifically on inhibitory control, a component of the self-regulatory component of temperament, as a risk factor for temperamentally reactive children (Henderson et al., 2015; Henderson & Wilson, 2017). Inhibitory control refers to one's ability to inhibit a dominant response in favor of a subordinate response and is a key component of temperamental effortful control during the preschool period (Rothbart et al., 2001, 2003; Rothbart & Bates, 2006). Henderson and her colleagues (Henderson et al., 2015; Henderson & Wilson, 2017) suggest that children with temperamental styles characterized by novelty sensitivity are marked by a reactive default mode of processing brought on by a developmental history of automatically orienting towards a perceived threat. To help regulate the negative emotions associated with reactive children's automatic orientation towards the perceived threat, the controlled processing network is frequently recruited and functions to potentiate, rather than eliminate, the fear already present. The combination of frequently activating both the reactive and controlled modes of processing presumably creates a positive feedback loop where children with higher levels of reactivate temperaments (e.g., shyness) and inhibitory control may spend more time monitoring their environment and perceive higher levels

of threat in benign social situations. This over-monitoring may lead to overregulated behavioral responses and cognitive perceptions, limiting children's ability to engage flexibility with their environment.

There has been empirical support for the risk potentiation model of control across childhood using different measures of reactive temperament, including behavioral inhibition, social fear, and shyness. Before reviewing the extant literature, it is important to highlight that theoretical accounts of shyness typically propose that shyness is rooted in early behavioral inhibition, which is characterized by fear of novelty in both non-social and social contexts (Fox et al., 2001; Kagan, 1999; Kagan et al., 1984). In addition to behavioral inhibition, other temperamental styles that share some conceptual overlap with shyness include dysregulated fear (K. A. Buss, 2011; K. A. Buss et al., 2013), social fear (Brooker et al., 2016; Walker et al., 2015), fearful temperament (Morales et al., 2015), temperamental reactivity (Rothbart & Bates, 2006), social reticence (Asendorpf, 1990; Coplan et al., 1994), social withdrawal (Hane et al., 2008), and anxious solitude (Gazelle & Ladd, 2003). However, most of the extant literature supporting the risk potentiation model of control has used behavioral inhibition as an index of reactive temperament.

In two studies, behavioral inhibition was only positively associated with symptoms of prospective social (Thorell et al., 2004) and general (L. K. White et al., 2011) anxiety when inhibitory control was relatively high during early childhood. Here, inhibitory control was indexed using cognitive laboratory tasks. A different study using a longitudinal index of inhibitory control operationalized as Go/Nogo task performance measured at 5, 7, and 10 years found that behavioral inhibition in toddlerhood was only positively associated with prospective symptoms of social anxiety at 12 years at steep or moderately steep slopes of inhibitory control

performance (Troller-Renfree et al., 2019). Other studies have since used a longitudinal design and found that behavioral inhibition measured in toddlerhood was only associated with higher levels of prospective social reticence (Lamm et al., 2014) and higher social withdrawal and lower assertiveness at age 7 (Lahat et al., 2014) at relatively higher levels of the N2 amplitude (i.e., a neural correlate of cognitive control) in response to incongruent trials during a cognitive task.

Studies using social fear and negative emotionality provide converging evidence. For example, social fear was only positively associated with prospective anxious behaviors with peers at age 5 at relatively high levels of inhibitory control measured at age 2 (Brooker et al., 2016). Similarly, negative emotionality during the preschool period was only positively associated with prospective internalizing difficulties when children's percentile on a cognitive index of inhibitory control was relatively high (Rodrigues et al., 2021). Together, this collection of studies provides support for the risk potentiation model of control when conceptualizing reactive temperament as behavioral inhibition, social fear, or negative emotionality, and controlled cognitive processes as either inhibitory control or a neural correlate of cognitive control.

Studies focusing more specifically on shyness are largely in line with the studies using measures of behavioral inhibition, social fear, and negative emotionality. For example, shyness was negatively associated with parent-reported prosocial behaviors and popularity at high levels of parent-reported inhibitory control and positively associated with teacher-reported regulated school behaviors at low levels of inhibitory control in a sample of Italian preschoolers (Sette et al., 2018). A different cross-sectional study of 9–13-year-old children found that at relatively high levels of the N2 amplitude in response to incongruent trials during a cognitive task, shyness was associated with a negative attributional style, lower self-perceived peer acceptance, and

symptoms of social anxiety (Henderson, 2010). Similarly, a more recent study conducted during early childhood found when children exhibited relatively large baseline-to-task decreases in EEG theta/beta ratio from baseline to a social stressor, presumably indicative of relatively high neurocognitive control, shyness was cross-sectionally related to trait and state social anxiety (Poole et al., 2021).

In a different recent cross-sectional study, preschoolers were observed during a model building task that included either a familiar (i.e., with their mother) or unfamiliar (i.e., with a novel adult female) social partner (Hassan & Schmidt, 2022b). In the unfamiliar context, shyness was only negatively associated with social support seeking at relatively high levels of a multimethod index of inhibitory control, supporting the risk potential model of control. In the familiar context, however, shyness was only positively associated with social support seeking at relatively high levels of inhibitory control (Hassan & Schmidt, 2022b). The results from this study provide further support for the risk potentiation model of control and suggest contextual factors such as familiarity may influence these relations. It is important to note, however, that a different study using a sample of preschoolers failed to find that maternal report of inhibitory control moderated the association between shyness and observed social behavior in the laboratory (Hassan et al., 2020). Differences between this study and the other studies may be due to observed versus parent-reported inhibitory control, and parent-reported versus observed social behavior. Together, these studies, using various indices of cognitive control, provide support for the risk potentiation model of control, suggesting that inhibitory control may increase the risk for psychosocial difficulties across childhood in the context of temperamental styles marked by reactive modes of responding, such as shyness.

Gaps in the Extant Literature

There are several important limitations worth highlighting in the extant literature evaluating the risk potentiation model of control. First, most previous work relies on parent or teacher report of psychosocial outcomes rather than observed behavior (Henderson, 2010; Poole et al., 2021; Rodrigues et al., 2021; Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011). At least two of the studies that do use direct observation of social engagement include adults rather than peers as social partners (Hassan et al., 2020; Hassan & Schmidt, 2022b). Direct observation of social behavior, particularly with peers, is important to consider because the risk potentiation model of control suggests that one consequence of high levels of shyness and inhibitory control is restricted and nonflexible social behavior (Henderson et al., 2015; Henderson & Wilson, 2017). Direct observation of social behavior is important because parental reports of social behavior may not align with how children truly behave in social situations with their peers and may therefore increase ecological validity. Further, friendships and peer acceptance are protective against psychopathology across childhood (M. E. Schmidt & Bagwell, 2007; Schwartz et al., 2000; Sette et al., 2017), and so it is important to determine factors that influence children's ability to engage in positive social interactions with their peers.

A second important gap to consider is a lack of considering how shyness and inhibitory control influence the child's own behavior (i.e., actor effects) as well as their partner's social behavior (i.e., partner effects). An actor-partner independence model (APIM) allows for a focus on the dyad rather than the individual child as the unit of analysis and provides estimates of how variables of interest influence the child's own and the partner's behavior while accounting for dyadic interdependence (Cook & Kenny, 2005). While the extant literature does suggest that shyness and related constructs are negatively related to a child's own approach related behaviors and positively related to the child's own levels of anxiety and avoidance-related behaviors (i.e.,

actor effect) (Henderson, 2010; Lahat et al., 2014; Lamm et al., 2014; Poole et al., 2021; Rodrigues et al., 2021; Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011), it remains unclear if a child's shyness and inhibitory control influence their partner's social behavior (i.e., partner effect). One study did include a measure of coded social behavior in the presence of an unfamiliar peer, but only actor effects were included in the reported analyses (Lamm et al., 2014).

To our knowledge, only two previous studies have examined the influence of fearful temperament on actor and partner effects of social behavior. In a study where 39-month-old children were paired with an unfamiliar same-sex peer, children's parent-reported social fearfulness was negatively related to their own observed assertiveness, but not to their social partner's assertiveness (McElwain et al., 2014). In a more recent similarly designed study where children were paired with an unfamiliar same-sex peer, parent-report of social fear at 24 months was negatively related to the child's own and their partner's social engagement, positively related to the child's own social wariness, and positively related to the partner's observed dysregulation at 36 months (Walker et al., 2015). Here, there is at least preliminary evidence suggesting that temperamental factors related to shyness are associated with differences in actor and partner effects on social behavior, but it remains unclear whether inhibitory control moderates these relations. This is an important gap to consider because children's behavior does not exist in isolation, and social interactions are dynamic. If relatively high levels of shyness and inhibitory control are related to a target child's own inflexible behaviors, does this combination also influence the partner's social behavior in the same direction, or does the social partner adjust their behavior to compensate for the child's inflexibility?

The Present Study

Using an APIM (Cook & Kenny, 2005), the goal of the present study was to examine whether a multimethod index of inhibitory control at age 3 moderated the relation between shyness measured at age 3 and the child's own and their social partner's observed social behavior with an unfamiliar peer approximately 1.5 years later. We focused on preschoolers because of the increases in self-regulatory processes that are occurring during this period (Dennis et al., 2007; Geeraerts et al., 2021; Klenberg et al., 2001; Kochanska et al., 1996; Schoemaker et al., 2014; Williams et al., 1999) before formal school entry and to increase comparability with other studies examining the moderating role of inhibitory control on the relation between shyness or related constructs and psychosocial outcomes (Brooker et al., 2016; Hassan et al., 2020; Rodrigues et al., 2021; Sette et al., 2018; Thorell et al., 2004; L. K. White et al., 2011). We also focused on broad measures of social approach and social avoidance in the present study to mirror earlier work (Walker et al., 2015).

In line with previous studies (Brooker et al., 2016; Henderson, 2010; Lahat et al., 2014; Lamm et al., 2014; Rodrigues et al., 2021; Sette et al., 2018; Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011), we predicted that shyness would be positively related to the child's own social avoidance and negatively related to social approach at relatively high levels of inhibitory control (i.e., actor effect). We did not make specific predictions about partner effects because no previous studies have examined the influence of the child's own shyness and inhibitory control on their social partner's observed behavior.

Method

Participants

Participants were 105 typically developing 3-year-old children (52 girls, M_{age} = 3.50 years, SD_{age} = 0.19 years) and their parents who were recruited from the Child Database in the Psychology,

Neuroscience & Behaviour at McMaster University in Ontario, Canada. This database contains the names and contact information of parents of healthy, full-term newborn infants recruited from hospitals across the greater Hamilton metropolitan area who consented to participate in future infant and child studies conducted at McMaster University. Most of the children were White (87%), and their families had a mean household income of between $75,000 and $100,000 in Canadian dollars. Data collection occurred between 2017 and 2019.

Procedure

The present study was part of a larger study examining the influence of temperament on children's prospective social and emotional outcomes across the preschool period. Children and their parents visited the Child Emotion Laboratory at McMaster University at Time 1 (T1) when the children were three years old. At T1, the child, parent, and one female experimenter began in a room together. While the child played with a puzzle, the experimenter explained the study procedures to the parent. Once the child was acclimated to the laboratory room, the parent went into a separate room in the laboratory to complete a series of questionnaires. The parent could view the child on a closed-circuit computer monitor in the separate laboratory room while the child completed tasks. The child completed a Flanker Task on an iPad from the NIH Toolbox Cognitive Battery for preschool-aged children (Zelazo et al., 2013) followed by a dinky toys task (Goldsmith et al., 1993).

Parents and their children returned to the laboratory for a second time approximately one year later (Time 2; T2) where the child was paired with another same-sex and unfamiliar child who had also participated in the T1 visit (M_{age} at T2 = 4.76 years SD_{age} = 0.38 years). The dyad met for the first time in the playroom and proceeded to engage in play activities. The parent was present for the first portion of the play activities, then left the room to complete a series of

questionnaires. As with T1, the parent could view the child on a closed-circuit computer monitor while they filled out the questionnaires and the child interacted with the unfamiliar peer. All families were provided with small toys, *Junior Scientist* certificates, and $30 gift cards as tokens of appreciation for their participation. Parents provided written consent and children provided verbal assent for both visits. All procedures were approved by the McMaster Research Ethics Board.

Measures

Shyness (T1)

Parent Report. Shyness was parent-reported using the 6-item shyness subscale from the Children's Behavior Questionnaire (CBQ) (Rothbart et al., 2001). Statements were rated by parents on a scale ranging from 1 (never) to 7 (always). A sample item from this scale includes "Acts shy around new people". The shyness subscale demonstrated good internal consistency (α = .89).

Inhibitory Control (T1)

Parent Report. Parents completed the Children's Behavior Questionnaire (CBQ), which is a parent-rated questionnaire evaluating 3- to 7-year-old children's temperament (Rothbart et al., 2001). Of particular interest to the present study were parental ratings of inhibitory control. On this 14-item scale, parents rate items on a 7-point scale with 1 = *Never* and 7 = *Always*. Mean scores were computed, and thus scores could range from 1 to 7. A sample item from the inhibitory control scale is "Can wait before entering into new activities if s/he is asked to", and the scale exhibited strong internal consistency (α = .82).

Dinky Toys Task. This task is a measure of inhibitory control that was adapted from a previous study (Kochanska et al., 1996) and the Preschool Lab-TAB (Goldsmith et al., 1993).

The experimenter and child were seated cross-legged across from each other on the floor, and the child was presented with a box of attractive dinky toys and asked to indicate using their words which toy they would like while keeping their hands on their lap. The experimenter then slid the box over to the child and reminded the child to keep their hands on their lap before removing the lid of the box. The child then either told the researcher which toy they wanted or grabbed the toy. The experimenter gave the child one more reminder to keep their hands on their lap if a choice was not made within 5 seconds. Following the first choice, the child was told, "Because you did such a good job today, I'm going to let you pick another prize to take home." The procedure was then repeated.

Performance on the dinky toys task was unobtrusively digitally recorded and was subsequently coded. Children's strategy was coded on a 0- to 5-point scale, following the coding scheme of Kochanska et al. (1996). A 0 was assigned if the child grabbed the toy out of the container; a 1 was assigned if the child touched the toys in the container but did not take a toy out; a score of 2 was given if the child pointed to the toys but did not touch them; a 3 was assigned if the child removed their hands from their lap but did not touch the toy; a 4 was assigned if the child's hands twitched or moved slightly but did not leave the lap; and a 5 was assigned if the child did not move their hands from their lap. Because this task was completed twice and the scores were highly correlated ($r = .73$, $p < .001$), scores for children's strategies were averaged between the two trials. To establish reliability, independent coders overlapped on 18% of the videos and good interrater reliability was established (κ trial 1 = .95; κ trial 2 = .96).

Flanker Task. The Flanker Task from the NIH Toolbox Cognitive Function Battery was used to measure cognitive inhibitory control which was administered using an iPad (Zelazo et al., 2013). During this task, the child was first presented with a row of fish and was instructed to

press the button that matched the direction that the middle fish was pointing. This task consisted of congruent trials where all the fish were facing the same direction and incongruent trials where all the fish were facing the opposite direction from the middle fish. If the child performed above a certain cut-off point, they completed a second version of this task where they saw arrows instead of fish. The Flanker Task consisted of 4 practice trials, 20 trials using fish as stimuli, and 20 trials using arrows as stimuli. Detailed information on how scoring is computed is described elsewhere (Zelazo et al., 2013). Each child was given a percentile based on their standardized, age-corrected score.

Composite Measure. A composite measure of inhibitory control was derived that included CBQ maternal report of inhibitory control, coded behavior from the dinky toys task, and cognitive performance on the Flanker Task. A confirmatory factor analysis supporting the use of a composite of inhibitory control has been previously published in a separate paper examining the curvilinear relation between inhibitory control and avoidant social behaviors (see Hassan & Schmidt, 2022a). Given the high number of associations accounted for in an APIM, and because of our relatively limited sample size, we elected to use an observed rather than latent variable of inhibitory control. All three variables were significantly, positively correlated (rs > .17, ps < .045), and so scores for all three measures were z-scored and summed. Higher values on this composite represented relatively higher levels of inhibitory control.

Observed Dyadic Social Behavior (T2)

Children's approach and avoidance behavior was observed in a free play context with an unfamiliar peer with the parent present and separately without the parent present. During these interactions, the research assistant brought in a large plastic bin filled with different toys (e.g., puzzles, blocks, dolls, cars) into the playroom and told the children they had 10 minutes to play

with the toys in the bin together, and then she left the room. After 10 minutes, the research assistant returned to the room and told the children it was time for their next activity. Children's social behavior was unobtrusively digitally recorded and was subsequently coded by independent research assistants, and behavioral codes were heavily adapted from the Play Observation Scale (see Rubin, 2001).

Approach Behavior. Children's positive affect and prosocial acts/cooperation behaviors were coded every 10 seconds. Positive affect in both the free play session with and without the parents was based on facial (e.g., upturned lips, smiling), verbal (e.g., giggling, singing), and behavioral displays (e.g., skipping, dancing) on a scale of 1 (none displayed) to 4 (continued mild or stronger expression >7 seconds; two or more distinct, strong expressions; four or more distinct, mild-to-moderate expressions). Prosocial acts/cooperation were defined as positive and friendly actions that demonstrated one child understood or recognized the needs or intentions of the other child. Prosocial acts/cooperation included sharing, helping, comforting, giving, and cooperating, and were coded on a scale of 1 (none displayed) to 4 (three or more instances of the behavior occur, one or two behaviors occur, but they last for 5 or more seconds) with the parent. Although prosocial acts/cooperation were also coded without the parent present, that variable was not significantly correlated with the other measures of positive affect and prosocial acts/cooperation with the parent (*ps* = .076 to .807), and so it was not included in the composite. Because of small delays (e.g., 15 seconds) in ending the play episode, proportion scores were used where the sum of each behavior was divided by the number of minutes the play episode lasted. Positive affect with (κ = .89) and without the parent (κ = .83) and prosocial acts/cooperation with the parent (κ = .78) exhibited acceptable to excellent interrater reliability. All variables were either marginally or significantly related (*r*s = .25 to .58, *p*s = .057 to < .001),

and so scores were *z*-scored and summed. Higher values on this composite represented relatively higher levels of approach behavior.

Avoidant Behavior. Children's negative affect and unoccupied/onlooking behaviors were coded every 10 seconds. Negative affect in both the free play session with and without the parents was based on facial (e.g., pouting lips, frowning), verbal (e.g., crying, whining), and behavioral displays (e.g., hanging head, slacked posture) on a scale of 1 (none displayed) to 4 (continued mild or stronger expression >7 seconds; two or more distinct, strong expressions; four or more distinct, mild-to-moderate expressions). Unoccupied/onlooking behavior was operationalized as the child staring blankly into space or wandering around with no specific purpose and was coded when it was displayed the most out of several other mutually exclusive play behaviors derived from the Play Observation Scale (Rubin, 2001). Although this behavior was coded in the free play sessions both with and without the parents present, the instance was very low when the parents were present. As such, we focused only on unoccupied/onlooking behavior in the free play session without the parents present. Because of small delays (e.g., 15 seconds) in ending the play episode, proportion scores were used where the sum of each behavior was divided by the number of minutes the play episode lasted. Negative affect with (κ = .87) and without the parent (κ = .84) and unoccupied/onlooking without the parent (κ = .86) exhibited acceptable to excellent interrater reliability. Like the inhibitory control composite measure, a confirmatory factor analysis supporting the use of a composite of avoidant behaviors has been previously published in a separate paper examining the curvilinear relation between inhibitory control and avoidant social behaviors (Hassan & Schmidt, 2021). Given the high number of associations accounted for in an APIM, and because of our relatively limited sample size, we elected to use an observed rather than latent variable of avoidant behavior. All variables were

significantly correlated (rs > .30, ps < .024), and so scores were z-scored and summed. Higher values on this composite represented relatively higher levels of avoidant behavior.

Missing Data and Loss to Follow Up

This present study was part of a larger study examining the influence of temperament on prospective social relationships in preschool children and included both a dyadic and individual visit at T2. The variables of interest in the present study occurred during the dyadic portion of T2. Because it was difficult to align schedules of families with children of the same-sex for the dyadic portion, of the 105 children at T1, 62 children returned for their T2 dyad visit. Two children at T2 were matched with a same-sex, same age child who had not been tested at the T1 visit because we were unable to align the schedules of these two children with any of the children tested at T1, and so a total of 64 children had T2 dyad data. The retention rate for children who returned to complete an individual visit at T2 rather than the dyadic portion at T2 was n = 71. Of the 105 at T1, 2 were missing maternal-report of shyness data due to refusal to participate.

The children who did not complete the T2 dyadic portion did not differ from those children that did based on age ($t(104) = 0.40$, $p = .693$), sex (X^2 (1, N = 105) = 1.01, $p = .31$), household income ($t(98) = -0.48$, $p = .629$), Flanker percentile ($t(86) = -0.23$, $p = .824$), dinky toys coded behavior ($t(101) = -0.40$, $p = .693$), maternal-report of inhibitory control ($t(102) = -0.42$, $p = .967$), or maternal-report of shyness ($t(102) = 0.41$, $p = .682$).

Little's Test of Missing Completely at Random (MCAR) was not significant, $\chi 2 = 14.36$, df = 20, $p = .811$, suggesting that patterns of missing data did not violate the assumption that data were missing completely at random. To leverage the full sample (N = 105), children who did not return for the second visit were given a dyad pairing value based on same-sex matching and the

date of their T1 visit, and full information maximum likelihood (FIML) was used to account for missing data in the APIMs presented below. This approach uses all available raw data to simultaneously account for all of the missing data and estimates model parameters and standard errors, thus avoiding the biased parameter estimates that can occur with pairwise or listwise deletion (Schafer & Graham, 2002).

Statistical Analyses

To examine the influence of a child's own shyness and inhibitory control at T1 on their own and their partner's approach and avoidant social behavior at T2, we used an Actor—Partner Interdependence Model (APIM; Cook & Kenney 2005). APIMs are a useful way to analyze dyadic data because they account for interdependence and provide estimates for both actor and partner effects. Conceptual and statistical interdependence is important to account for because the behavior of one member of the dyad may depend on the behavior of the other member of the dyad.

Dyadic influence was modeled in Mplus version 8 using two separate APIMs. Good and acceptable model fit to data was determined through several indices, including root mean square error of approximation (RMSEA) ≤ .060 and ≤ .080, comparative fit index (CFI) and Tucker–Lewis Index (TLI) of ≥. 950 and ≥.900, and standardized root mean residual (SRMR) ≤ .050 and ≤ .080 (Browne & Cudeck, 1992; Hooper et al., 2008; Hu & Bentler, 1999; Kline, 2015). In the present study, members of the dyads were considered indistinguishable because each member of the dyad was a part of a same-sex pair (Cook & Kenny, 2005; Walker et al., 2015). Children were therefore included as both actors and partners in a pairwise dataset. Because dyad members were indistinguishable, actor-actor and partner-partner paths were constrained to be equal, and

actor-partner and partner-actor paths were constrained to be equal (DeLay et al., 2021; Olsen & Kenny, 2006)

Predictors were the partner and the actor's shyness, inhibitory control, and the interaction between shyness and inhibitory control. Because the dyads were indistinguishable and inhibitory control served as a between-subjects moderator, there were 4 possible interaction effects: actor's shyness by actor's inhibitory control; partner's shyness by partner's inhibitory control; actor's shyness by partner's inhibitory control; partner's shyness by actor's inhibitory control (Garcia et al., 2015). The outcome was observed approach or avoidance related behavior in the dyadic free play sessions. Figure 3.1 provides a visual representation of this theoretical model.

Given the high number of relations modeled in an APIM, guidelines for moderation in APIMs suggests only including theoretically meaningful interaction terms (Garcia et al., 2015). Because the risk potentiation model of control focuses on the interaction between shyness and inhibitory control *within* individuals, we only included the actor's shyness by the actor's inhibitory control, and the partner's shyness by the partner's inhibitory control, as interaction terms in the two APIMs.

Results

Preliminary Analyses

Table 3.1 includes the means, standard deviations, and intercorrelations among study variables. Although sex was not related to mean level differences in shyness, observed approach, or observed avoidance ($ps \geq .126$), sex was associated with mean differences in inhibitory control, $t = 1.59$, $df = 101$, $p = .021$, where girls ($M = 0.13$, $SD = 0.73$) displayed significantly higher inhibitory control than boys ($M = -0.18$, $SD = 0.62$). Household income was only marginally related to inhibitory control ($r = .17$, $p = .094$), and unrelated to shyness, observed

approach, or observed avoidance (*p*s ≥ .201). Following a previous paper published with the same data set examining a separate question related to inhibitory control (Hassan & Schmidt, 2022a), we elected to control for sex and household income in the following analyses.

APIM Analyses

Observed Approach. The APIM including observed approach demonstrated good fit, X^2 = 3.25, *df* = 11, *p* = .987, RMSEA = 0, CFI = 1, TLI = 1, SRMR = .03. All estimates presented controlled for sex and household income. Table 3.2 depicts the parameter estimates for the complete APIM.

The actor effect of shyness was a nonsignificant predictor of observed approach (β = -0.15, *p* = .246). The actor effect of inhibitory control (β = 0.70, *p* = .004) and the interaction between actor shyness and actor inhibitory control (β = -0.30, *p* = .048) were significant predictors of approach behaviors. The partner effect of shyness (β = -0.17, *p* = .275) and the interaction between partner shyness and partner inhibitory control (β = -.34, *p* = .062) were not significant predictors of observed approach. The partner effect of inhibitory control also significantly predicted observed approach (β = 0.75, *p* = .006). Because the interaction is prioritized over the main actor and partner effects, we focused on interpreting the interaction.

To decompose the actor effect of the interaction between shyness and inhibitory control, we conducted a simple slopes analysis where we examined the relation between the actor effect of shyness and observed approach at high (one standard deviation above the mean) and low (one standard deviation below the mean) values of the actor effect of inhibitory control (Aiken & West, 1991; Dawson & Richter, 2006). At low values of inhibitory control, the child's own shyness was not significantly associated with their own observed approach behavior (β = 0.05, *p*

= .773). At high values of inhibitory control, the child's own shyness was negatively associated with their own observed approach behavior (β = -0.35, *p* = .017).

Observed Avoidance. The APIM including observed avoidance demonstrated good fit, $X^2 = 4.30$, *df* = 15, *p* = .998, RMSEA = 0, CFI = 1, TLI = 1, SRMR = .04. All estimates presented controlled for sex and household income. Table 3.3 depicts the parameter estimates for the complete APIM.

The actor effect of shyness (β = -0.10, *p* = .407), inhibitory control (β = .54, *p* = .073), and the interaction (β = -0.42, *p* = .068) did not significantly predict observed avoidance. The partner effect of shyness was also a nonsignificant predictor of observed avoidance (β = 0.03, *p* = .827). The partner effect of inhibitory control (β = -0.61, *p* = .034), and the partner effect of the interaction between shyness and inhibitory control (β = -0.80, *p* = .002) were significant predictors of observed avoidance. Because the interaction is prioritized over the main actor and partner effects, we focused on interpreting the interaction.

To decompose the partner effect of the interaction between shyness and inhibitory control, we conducted a simple slopes analysis where we examined the relation between the partner effect of shyness and observed avoidance at high (one standard deviation above the mean) and low (one standard deviation below the mean) values of the partner effect of inhibitory control (Aiken & West, 1991; Dawson & Richter, 2006). At low values of inhibitory control, the child's own shyness was positively associated with the partner's observed avoidance behavior (β = 0.59, *p* = .021). At high values of inhibitory control, the child's own shyness was negatively associated with the partner's observed avoidance behavior (β = -0.50, *p* = .019).

Discussion

Using an actor-partner independence model and a longitudinal approach, we examined whether age 3 inhibitory control moderated the relation between age 3 shyness and observed social approach and observed social avoidance with an unfamiliar peer at age 4.5. We found that children's shyness was only negatively associated with their own observed approach when their own inhibitory control was relatively high. We also found that when children's inhibitory control was relatively low, children's shyness was positively related to their partner's observed avoidance, but when children's inhibitory control was relatively high, shyness was negatively associated with the partner's observed avoidance behavior.

The risk potentiation model of control predicts that relatively high levels of reactive temperament and inhibitory control would be related to more apprehension and more adaptive social behavior. As such, the finding that children's shyness was only negatively associated with their own observed approach behaviors with an unfamiliar peer when their own inhibitory control was relatively high was in line with predictions made by the risk potentiation model of control (Henderson et al., 2015; Henderson & Wilson, 2017). Empirically, our results are in line with previous studies suggesting that more reactive temperamental styles such as behavioral inhibition (Lahat et al., 2014; Lamm et al., 2014; Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011), shyness (Henderson, 2010; Poole et al., 2021; Sette et al., 2018), and negative emotionality (Rodrigues et al., 2021) are positively related to problematic emotional, social, and psychological difficulties in preschoolers, young children, and adolescents in the context of relatively high inhibitory control. Our results extend previous work by using a multifaceted measure of inhibitory control, extending cross-sectional work by employing a longitudinal design, and moving beyond parent-reports of anxiety and social behavior to observed social behavior with an unfamiliar peer. In line with the risk potentiation model of

control, we speculate that children with relatively high levels of shyness may have a developmental history of frequently and automatically orientating towards threat, and relatively high levels of inhibitory control lead to less approach-related behaviors by potentiating, rather than regulating, the social fear shy children are experiencing in unfamiliar social situations. Given that our measure of approach-related behaviors encompassed positive affect and prosociality, we speculate that the potentiation of fear may be related to higher levels of behavioral apprehension and inhibition possibly resulting in less positive affect and prosocial behaviors.

We did not make specific predictions about partner effects in the present study because we know of no previous studies that have examined the risk potentiation model of control in the context of a dyadic interaction. It is reasonable to predict that a combination of high levels of reactive temperament and inhibitory control may lead to less approach and more avoidance in the social partner, given the higher levels of anxiety and lower levels of social approach observed in shy and overcontrolled children. However, it is also reasonable to predict that children may compensate behaviorally for their shy and overcontrolled social partner's rigidity and respond with more approach and less avoidance. In partial support for the latter prediction, we found that when children's inhibitory control was relatively low, children's shyness was positively related to their partner's observed avoidance behaviors, but when inhibitory control relatively high, children's shyness was negatively related to their partner's observed avoidance behaviors.

The present findings are a particularly important extension of previous work because they suggest that the "negative" consequences of being highly shy and overcontrolled may be limited to the child's own behavior, and not necessarily reflected in how unfamiliar children respond to that child in a social context (Henderson et al., 2015; Henderson & Wilson, 2017). Consistent

with more traditional or top-down views of regulatory processes (Henderson et al., 2015), high levels of inhibitory control may act as a protective factor against the typically negative associations observed between shyness and social outcomes (Asendorpf & Meier, 1993; Coplan et al., 2008; Crozier & Perkins, 2002; Hassan & Schmidt, 2021; Poole & Schmidt, 2021). We speculate that unfamiliar peers may compensate for the less approach-related behavioral patterns of their shy and overregulated counterparts by displaying less avoidance.

It is possible that shy and overcontrolled children are unable to benefit from the partner effects observed in the present study, as evidenced by their lower levels of approach we observed and higher levels of anxiety observed in different studies (Brooker et al., 2016; Henderson, 2010; Poole et al., 2021; Rodrigues et al., 2021; Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011). If high levels of inhibitory control work to potentiate shy children's social fear (Henderson et al., 2015), these children may be spending more time attending to threat-related information rather than their social partner's low levels of avoidance related behavior. Later, if these children ruminate or engage in post-event processing of the social interaction, they may selectively recall information that supports their negative, fear-based cognitions, thereby perpetuating their fear and apprehension in future social situations (Henderson et al., 2015; Schmitz et al., 2010; van Niekerk et al., 2017). To provide empirical support for these speculations, future studies can use a combination of eye-tracking technology during a social interaction to determine where children's attention is during a social interaction (Pérez-Edgar et al., 2020), and children can self-report how well they thought their social interaction went with an unfamiliar peer. The reported partner effects in the present study provide support for the dynamic nature of children's social development that depend on both the child's own characteristics and the context surrounding the child, including their peers (Wachs &

Kohnstamm, 2001), and highlight the importance of examining the child's own behavior in addition to their social partner's behavior when considering children's social development.

Strengths, Limitations, and Future Directions

The results of the present study should be interpreted within its strengths and limitations. Strengths of the present study included a longitudinal design during a developmentally sensitive period for self-regulation prior to formal school entry (Dennis et al., 2007; Geeraerts et al., 2021; Klenberg et al., 2001; Kochanska et al., 1996; Schoemaker et al., 2014; Williams et al., 1999), and a theoretically driven empirical test of the risk potentiation model of control (Henderson et al., 2015; Henderson & Wilson, 2017) using observed social behavior with an unfamiliar peer and a dyadic analytical approach.

With respect to limitations, the observed attrition in the present study was relatively high. The high T2 attrition was in part due to difficulties associated with aligning the schedules of two unfamiliar children tested at T1. Importantly, missingness was not associated with any of the T1 variables of interest or sociodemographic variables, the patterns of missing data did not violate the assumption that data were missing completely at random, and the use of FIML should theoretically lead to less biased estimates than listwise deletion (Schafer & Graham, 2002).

Although one important extension of the present study was a test of the risk potentiation model of control using a dyadic analytical approach and a dyadic analysis, we do not know whether the actor and partner effects were specific to interactions with an unfamiliar social partner, or whether they would extend to a more familiar social partner. This is an important area for future search because at least one study has suggested that the predictions made by the risk potentiation model of control may be restricted to an unfamiliar social context (Hassan & Schmidt, 2022b)

Finally, our sample was relatively homogenous as the families were primarily White and the mean household income was relatively high. To account for the impact of socioeconomic status, we controlled for household income. Given the relatively high mean household income, however, it is possible that we did not a wide enough range of household incomes represented in the present study to fully account for the impact of household income on the results reported. The results from the present study may therefore not be generalizable to a more ethnically and socioeconomically diverse sample of children. Future studies should examine the reproducibility of the present results in more ethnically and economically diverse samples than used herein.

Conclusion

Guided by the risk potentiation model of control, we used an APIM to examine whether T1 inhibitory control moderated the association between T1 shyness and the actor and partner's T2 observed social approach and avoidance behavior. We found that shyness was negatively associated with the actor's own approach behaviors, and the partner's avoidance behaviors, at relatively high levels of inhibitory control. We speculate that unfamiliar social partners may compensate for the relatively lower levels of approach behaviors in shy and overcontrolled children by displaying less avoidance, but that shy and overcontrolled children may not benefit from this social information because of a developmental history of threat sensitivity and excessive controlled processing. The results from the present study provide further empirical support for the risk potentiation model of control and extend previous studies using this model by empirically demonstrating differences in actor and partner effects in relation to shyness and inhibitory control on children's observed social behavior with an unfamiliar peer.

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Table 3.1

Pearson's Correlations and Descriptive Statistics for Study Variables

Variables	2	3	4	Mean (*SD*)	Range
1. Shyness (T1)	-.07	-.01	-.08	3.51 (1.26)	1 to 6.67
2. Inhibitory Control (T1)	-	-.17	.11	-0.02 (0.69)	-1.75 to 1.71
3. Approach Behavior (T2)	-	-	-.05	0.06 (2.34)	-3.28 to 6.72
4. Avoidance Behavior (T2)	-	-	-	-0.06 (2.52)	-2.65 to 9.08

T1 = Time 1; T2 = Time 2

Table 3.2

Actor-Partner Interdependence Model Depicting the Influence of Shyness, Inhibitory Control, and their Interaction at Time 1(M_{age} = 3.50 years) on Observed Approach Behaviors during a Dyadic Free Play Session at Time 2 (M_{age} = 4.76 years)

A = actor effect; P = partner effect

Predictor	*B*	*SE*	*p*
Shyness (A)	-0.15	0.13	.246
Shyness (P)	-0.17	0.15	.285
Inhibitory Control (A)	-0.70	.25	.004
Inhibitory Control (P)	0.75	.27	.006
Shyness (A) * Inhibitory Control (A)	-0.30	.15	.048
Shyness (P) * Inhibitory Control (P)	-0.34	.18	.062

Table 3.3

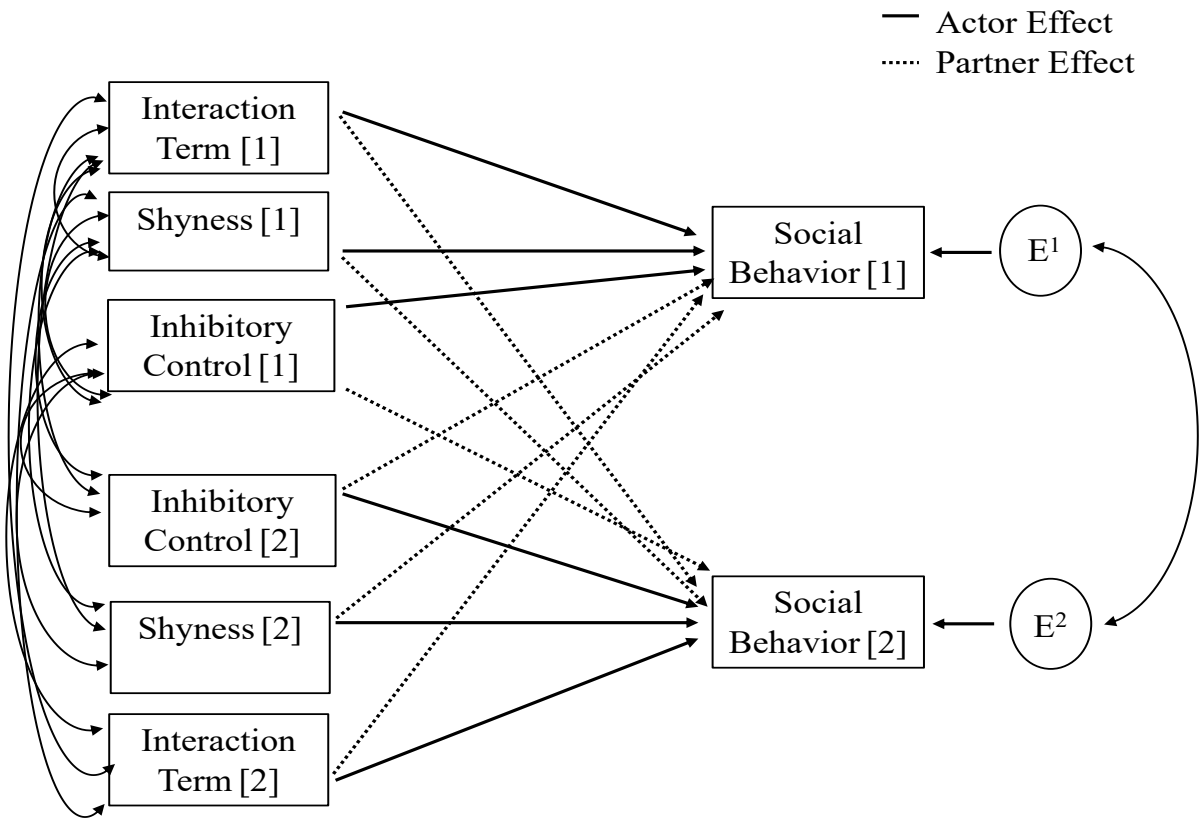
Actor-Partner Interdependence Model Depicting the Influence of Shyness, Inhibitory Control, and their Interaction at Time 1(M_{age} = 3.50 years) on Observed Avoidance Behaviors during a Dyadic Free Play Session at Time 2 (M_{age} = 4.76 years)

A = actor effect; P = partner effect

Predictor	*B*	*SE*	*p*
Shyness (A)	0.10	0.13	.407
Shyness (P)	0.03	0.15	.827
Inhibitory Control (A)	0.54	0.30	.073
Inhibitory Control (P)	-0.61	0.29	.034
Shyness (A) * Inhibitory Control (A)	-0.42	0.21	.068
Shyness (P) * Inhibitory Control (P)	-0.80	0.26	.002

Figure 3.1

Conceptual Illustration of the Actor-Partner Interdependence Model (APIM) of Shyness, Inhibitory Control, and their Interaction at Time 1(M_{age} = 3.50 years) Predicting Observed Social Behavior at Time 2 (M_{age} = 4.76 years)



Note. Sex and household income were not depicted in the presented model for clarity but were included in the model.

[1] = Child 1; [2] = Child 2; E = error residuals

CHAPTER 5

Study 4: Shyness, inhibitory control, and social support seeking in preschoolers: Role of familiar and unfamiliar contexts.

Hassan, R. & Schmidt, L.A. (Under Review). Shyness, inhibitory control, and social support seeking in preschoolers: Role of familiar and unfamiliar contexts. *Invited revision.*

Abstract

The risk potentiation model of cognitive control posits that inhibitory control may heighten the risk for problematic outcomes among some temperamental styles characterized by high reactivity. Because shyness is a temperamental style defined as wariness and heightened reactivity to social *novelty*, we examined whether the interaction between shyness and inhibitory control predicted social support seeking differently depending on context using a between-subjects design. Typically developing preschoolers (N = 167, 52% female, M_{age} = 4.05 years, SD_{age} = 0.77 years) were observed during a model building task that included a familiar (i.e., with their mother) or unfamiliar (i.e., with a novel adult female) social context. In the unfamiliar context, shyness was negatively associated with social support seeking at relatively high levels of inhibitory control, supporting the risk potentiation model of control. However, in the familiar context, we found that shyness was positively associated with social support seeking at relatively high levels of inhibitory control. These results suggest that high levels of inhibitory control may potentiate social fear for preschoolers who are also shy and that these relations may depend on contextual factors.

Introduction

Shyness is a moderately stable temperamental characteristic that refers to wariness, inhibition, and anxiety in novel social contexts (A. H. Buss, 1986; Cheek & Buss, 1981; Karevold et al., 2012; Sanson, 1996). Shy children presumably view social novelty as threatening and may have a difficult time regulating their fear and anxiety in social contexts. Indeed, shy children exhibit physiological profiles associated with stress reactivity and greater behavioral anxiety when faced with social challenges. For example, 7-year-old shy children exhibited greater increases in heart rate and anxious behavior during a self-presentation task compared to non-shy children (Schmidt et al., 1999). Shyness has also been associated with a high and steeply increasing trajectory of behavioral avoidance in novel social situations during the preschool period (Hassan & Schmidt, 2021a) and shy children have been found to speak less in unfamiliar social situations (Asendorpf & Meier, 1993; Crozier & Perkins, 2002; Evans, 1993). These behavioral correlates are frequently interpreted as a consequence of shy children's fear in social contexts. At the level of social relationships, although some studies have failed to find direct relations between shyness and negative social outcomes (Fordham & Stevenson-Hinde, 1999; Morneau-Vaillancourt et al., 2021), other studies have found that shyness was positively associated with peer difficulties (Coplan et al., 2008). Shyness and related constructs also have been consistently correlated with increased risk for internalizing problems (Chronis-Tuscano et al., 2009; Findlay et al., 2009), especially symptoms of social anxiety disorder characterized by a fear of negative evaluation (Chronis-Tuscano et al., 2009; Clauss & Blackford, 2012; Heiser et al., 2003, 2009; Hirshfeld-Becker et al., 2007; Poole et al., 2020; Poole, Van Lieshout, et al., 2017; Sandstrom et al., 2020). Together, these studies suggest that shyness is associated with behavioral avoidance in novel social situations, interpersonal

difficulties, and internalizing problems presumably because of shy children's social fear. However, not all shy children go on to experience these difficulties, so it is important to examine moderating factors that might help explain this heterogeneity. One possible moderator is self-regulation.

Self-regulation broadly encompasses the affective, behavioral, cognitive, and physiological processes which function to modulate reactivity and support goal-directed behavior (McClelland et al., 2010; Rothbart & Bates, 2006). Children's capacity to employ regulatory strategies at different levels of self-regulation is of critical importance to their adaptive functioning. For example, children with relatively higher levels of effortful control and related constructs may be more effective at building and maintaining positive social relationships with those around them than children with relatively lower levels of effortful control (Eisenberg et al., 2010; Wilson, 2003). Emotion regulation (Graziano et al., 2007) and behavioral regulation (Ponitz et al., 2009) also have been implicated in positive academic outcomes for kindergarteners and negatively associated with behavioral problems and mental health difficulties across childhood (Eisenberg et al., 2009, 2010).

Despite the positive associations between self-regulation and various psychosocial outcomes, there is emerging literature suggesting that some components of self-regulation may be maladaptive depending on individual differences in temperament. For example, the risk potentiation model of control posits that controlled cognitive processes such as inhibitory control—the capacity to inhibit a dominant response in favor of a subordinate response—may heighten the risk for socioemotional, psychological problems, and social fear in the context of temperamental styles characterized by heightened reactivity to sensory stimuli such as shyness (Henderson et al., 2015; Henderson & Wilson, 2017).

As highlighted by Henderson and her colleagues (Henderson et al., 2015; Henderson & Wilson, 2017), children with temperamental styles characterized by sensitivity to novelty are presumed to also have a reactive default mode of processing brought on by a developmental history of easily and automatically orienting towards a perceived threat. Here, attention is frequently drawn away from tasks when threat, novelty, or conflict between goals and environmental cues are detected. To help regulate the emotions associated with the reactivity to novelty and maintain goal-directed behavior, the controlled processing network is frequently recruited. Rather than regulating the fear, the processes associated with inhibitory control including holding rules in mind and closely monitoring and modifying behavior in response to goals, may keep children fixated on the attention-grabbing environmental cue rather than flexibly returning attention to the goal of the task (Fox et al., 2021). The reactive mode of responding paired with the controlled mode of responding frequently activated presumably creates a positive feedback loop where shy children with high inhibitory control may spend more time monitoring their environment and perceive higher levels of social threat in benign social situations resulting in more anxiety and fear. One behavioral consequence of this positive feedback loop is that shy children with high inhibitory control fail to engage flexibility with their environment and display more rigid behavioral responses in social situations.

Over the last two decades, there has been an increase in studies examining the moderating role of inhibitory control in the relation between behavioral inhibition—a construct related to shyness (e.g., Kagan et al., 1988; Poole et al., 2018; Poole, Jetha, et al., 2017; Schmidt et al., 1997)—and psychological and social maladjustment. Two separate studies found that behavioral inhibition was only positively associated with symptoms of prospective social (Thorell et al., 2004) and general (White et al., 2011) anxiety at relatively high levels of

inhibitory control assessed using cognitive laboratory tasks during early childhood. Another study using a longitudinal assessment of inhibitory control operationalized as performance on the Go/Nogo task measured at 5, 7, and 10 years found that behavioral inhibition measured in toddlerhood was only positively associated with prospective symptoms of social anxiety measured at 12 years at steep or moderately steep slopes of inhibitory control performance (Troller-Renfree et al., 2019). A different study examining social fear, rather than behavioral inhibition, also found that social fear was only positively associated with prospective anxious behaviors with peers at age 5 at relatively high levels of inhibitory control measured at age 2 (Brooker et al., 2016).

A similar pattern of results has been found when using shyness rather than behavioral inhibition as the predictor. For example, in a sample of preschoolers, shyness was negatively associated with parent-reported prosocial behaviors and popularity at high levels of parent-reported inhibitory control and positively associated with teacher-reported regulated school behaviors at low levels of inhibitory control (Sette et al., 2018). It is important to note, however, that a different study using a sample of preschoolers failed to find that maternal report of inhibitory control moderated the association between shyness and observed social behavior in two different social contexts in the laboratory (Hassan et al., 2020). Differences between Hassan and colleagues and the other aforementioned studies may be due to observed versus parent-reported inhibitory control, and parent-reported versus observed social behavior.

Studies that have used neurophysiological indices of controlled processes also provide support for the risk potentiation model of control. One cross-sectional study of 9–13-year-old children found that at relatively high levels of the N2 amplitude (i.e., a neural correlate of cognitive control) in response to incongruent trials during a cognitive task, shyness was

associated with a negative attributional style, poor perceptions of social acceptance, and symptoms of social anxiety (Henderson, 2010). Other studies have since used a longitudinal design and found that behavioral inhibition measured in toddlerhood was only associated with higher levels of prospective social reticence (Lamm et al., 2014) and higher social withdrawal and lower assertiveness at age 7 (Lahat et al., 2014) at relatively higher levels of the N2 amplitude in response to incongruent trials during a cognitive task. A more recent study conducted during early childhood found when children exhibited relatively large baseline-to-task decreases in EEG theta/beta ratio from baseline to a social stressor, presumably indicative of relatively high neurocognitive control, shyness was cross-sectionally related to trait and state social anxiety (Poole et al., 2021). Together, these studies, using behavioral and neural indices of cognitive control, provide support for the risk potentiation model of control, suggesting that inhibitory control may increase the risk for psychosocial difficulties through potentiation of fear across childhood in the context of temperamental styles marked by reactive modes of responding such as shyness.

While these studies provide us with important information about the double-edged sword of inhibitory control in the context of shyness and related constructs, they do not clarify the influence of contextual factors. Specifically, because shyness is defined as wariness in the context of social *novelty*, the risk potentiation model of control may depend on contextual familiarity (A. H. Buss, 1986; Cheek & Buss, 1981; Karevold et al., 2012; Sanson, 1996). If contextual familiarity impacted the interaction between shyness and inhibitory control to social behavior, such that the risk potentiation model was only applicable in unfamiliar contexts, this finding would have implications for practice and theory. Practically, it would suggest that the adaptiveness of inhibitory control for shy children could be manipulated by increasing contextual

familiarity, potentially improving shy children's social relationships and psychological outcomes. Theoretically, it would bring greater specificity to the risk potentiation model of control and suggest that the positive feedback loop initiated by the interaction between reactive and default modes of processing described by Henderson and her colleagues is not a forgone conclusion (Henderson et al., 2015; Henderson & Wilson, 2017). Rather, these findings would indicate that the negative impact of inhibitory control for shy children occurs because of modifiable contextual factors rather than instantiated processing patterns occurring indiscriminately.

Although no study to date, to our knowledge, has manipulated familiarity to determine whether the moderating role of inhibitory control differs in familiar versus unfamiliar contexts, other studies have found that direct relations between shyness and socioemotional outcomes may differ based on familiarity factors. For example, one early study found that shyness was negatively associated with helping behaviors observed in the laboratory (i.e., an unfamiliar context), but not in the home (i.e., a more familiar context) during the preschool period (Stanhope et al., 1987). Another study found that inhibited preschoolers were more likely to engage in dyadic interactions with a peer in their homes rather than outside the home when compared to non-inhibited children (Coplan et al., 2009). One speculation explaining these results may be that parents were more likely to organize social events in the home because the familiarity would reduce stress for the inhibited child, suggesting that parents may perceive their inhibited children as more comfortable and less anxious in familiar compared to unfamiliar contexts. An earlier study that more directly examined whether familiarity influences shy children's outcomes found that, although shy children spent less time in conversation in unfamiliar situations compared to non-shy children, there were no between-group differences in

familiar situations (Asendorpf & Meier, 1993). Because some relations between shyness and social behavior appear to differ based on context, the negative impact of inhibitory control on shy children's outcomes may also depend on contextual familiarity.

The Present Study

The goal of the present study was to examine the specificity of the risk potentiation model of control in typically developing preschoolers in familiar and unfamiliar contexts using a between-subjects design. To this end, social support seeking behaviors were coded while preschoolers built a model with either a novel female research assistant (i.e., unfamiliar context) or with their mother (i.e., familiar context). A composite measure of inhibitory control was derived using three different indicators of inhibitory control. To determine whether the results were specific to more social behaviors versus other non-social behaviors, we also coded children's persistence in building the model. We elected to focus specifically on preschoolers because of the increases in self-regulatory processes that are occurring during this period (Dennis et al., 2007; Geeraerts et al., 2021; Klenberg et al., 2001; Kochanska et al., 1996; Schoemaker et al., 2014; Williams et al., 1999) and to increase comparability with other studies examining the moderating role of inhibitory control on the relation between shyness or related constructs and psychosocial outcomes (Brooker et al., 2016; Hassan et al., 2020; Sette et al., 2018; Thorell et al., 2004; White et al., 2011).

Consistent with previous studies that have used an unfamiliar context to study the moderating role of controlled processes on the relation between shyness and related constructs and psychological or socioemotional outcomes (Brooker et al., 2016; Henderson, 2010; Lahat et al., 2014; Lamm et al., 2014; Poole et al., 2021; Sette et al., 2018; Thorell et al., 2004; Troller-Renfree et al., 2019; White et al., 2011), we predicted that shyness would be negatively

associated with social support seeking at high levels of inhibitory control. We also predicted that shyness would no longer be negatively related to social support seeking at high levels of inhibitory in the familiar context, because shyness largely originates and is maintained by social novelty (A. H. Buss, 1986; Cheek & Buss, 1981; Karevold et al., 2012; Sanson, 1996).

The analyses in the present study were therefore confirmatory rather than exploratory. However, the inclusion of persistence during the building task was exploratory rather than confirmatory, and therefore we did not make specific predictions about directionality for this measure. On one hand, we reasoned that shyness may be positively associated with persistence only in the unfamiliar condition at high levels of inhibitory control because shy and overcontrolled children may be more likely to follow directions to avoid negative social judgment from the unfamiliar adult. On the other hand, persistence is not a highly social behavior compared to social support seeking and may therefore be a less relevant outcome when examining the interaction among shyness, inhibitory control, and contextual familiarity.

Method

Participants

Participants were 167 3- to 5-year-old typically developing children (n_{female} = 87, M_{age} = 4.05 years, SD_{age} = 0.77 years) and their mothers who were recruited from the Child Database in the Department of Psychology, Neuroscience & Behaviour at McMaster University in Ontario, Canada. These participants were from a larger study of 184 participants, but the procedure for the model building task used to manipulate familiarity was not finalized until participant 19, so 167 had the potential to contribute data to the present study. The child database used to recruit participants contained the names and contact information of parents of healthy, full-term newborn infants recruited from hospitals across the greater Hamilton metropolitan area who

consented to be contacted in the future about infant and child studies conducted at McMaster University. Of the 167 children, the children were identified by parents as 85.6% White, 3% South Asian, 0.6% Chinese, 1.2% Black, 1.8% Latin American, 6.6% did not identify with any of these racial categories (e.g., Middle Eastern, Mixed Race), and 1.2% preferred not to answer. Of the reporting parents (typically the mother), 85.6% reported having a college diploma or higher; and 57% reported a mean household income of over $100,000 in Canadian dollars. Below, we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

Procedures

Children and their parent (typically the mother) participated in the present study at the Child Emotion Laboratory. The child, parent, and one female experimenter began in a room together. While the child played with a puzzle, the experimenter explained the study procedures to the mother. After written parental consent and verbal child assent were obtained, the parent left the room to complete a series of questionnaires. While in a separate room, the parent could view their child on a closed-circuit computer monitor. The child first completed the Flanker task from the National Institute of Health (NIH) Cognitive Battery for preschool-aged children (Zelazo et al., 2013), followed by a Lego model toy building task, with either an adult female stranger (unfamiliar condition) or their mother (familiar condition), before completing the Dinky Toys task (Kochanska et al., 1996). For condition consistency, the two participants who were accompanied to the laboratory by their fathers were assigned to the unfamiliar condition. The procedures are described in more detail below. Families received a $15 gift card, two small toys, and a *Junior Scientist* certificate for their participation. All procedures were approved by the McMaster Research Ethics Board.

Parental-Reported Measures

Children's Behavior Questionnaire (CBQ). Shyness and inhibitory control were parentally-reported using the 6-item shyness subscale and the 14-item inhibitory control scale from the CBQ (Rothbart et al., 2001). Statements were rated by parents on a scale ranging from 1 (never) to 7 (always). A sample item from the shyness scale includes "Acts shy around new people", and a sample item from the inhibitory control scale includes "Is good at games like "Simon Says," "Mother, May I?" and "Red Light, Green Light". The shyness ($\alpha = .89$) and inhibitory control consistency ($\alpha = .82$) scales demonstrated good internal consistency.

Demographics. A demographics questionnaire was also completed by the caregiver who brought the child into the laboratory.

Behavioral Tasks and Measures

NIH Toolbox: Flanker Task and Measure. Inhibitory control was also indexed using the Flanker task from the NIH Cognitive Battery for preschoolers. During this task, children were first presented with a row of fish and were instructed to press the button that matched the direction that the middle fish was pointing. This task consisted of congruent trials where all the fish were facing the same direction and incongruent trials where all the fish were facing the opposite direction from the middle fish. The Flanker task consisted of four teaching trials using fish as stimuli where two were congruent and two were incongruent, 25 trials using fish as stimuli where 16 were congruent and 9 were incongruent, and 25 trials using arrows as stimuli where 16 were congruent and 9 were incongruent. During the practice trials, children had to correctly respond to three out of four trials to move to the fish testing trials. If they failed to meet this criterion, they were exposed to a maximum of three more practice trials, and testing was terminated if they did not meet the passing criteria during any of those practice trials. Of the 167

children, 17 failed to pass the teaching trials, and all these children were 3 years of age. If the children responded correctly to 5 out of the 9 incongruent trials using fish as stimuli, they advanced to the final testing phase where arrows were used instead of fish. Scores were automatically computed by the NIH Toolbox using a two-vector system incorporating accuracy and reaction time for those who were accurate 80% or more of the time. The scoring system is described in more detail elsewhere (Zelazo et al., 2013). Age corrected percentiles computed by the NIH Toolbox were used for ease of interpretation where higher scores were indicative of relatively higher accuracy and speed compared to demographically matched peers.

Dinky Toys Task and Measure. Inhibitory control was also indexed using a modified version of the Dinky Toys task (Kochanska et al., 1996). During this task, the experimenter and child were seated cross-legged across from each other on the floor. The child was presented with a box of attractive toys and told to indicate using their words which they would like while keeping their hands on their lap. Once the experimenter slid the box over to the child, she gave the child up to two reminders to keep their hands on their lap before the child either told the researcher what toy they wanted or grabbed the toy. This task was repeated twice for reliability purposes and children's performance was averaged across trials. The child was allowed to switch the toy at the end of the task if they wished.

Children's behavior was subsequently coded from videos by independent coders on a zero to five-point scale (Kochanska et al., 1996). A zero represented the child grabbing a toy out of the container, a one represented the child touching the toys in the container, but not taking one out, a two represented the child pointing to the toys, a three represented the child removing their hands from the lap, a four represented the child's hands twitching or moving, but not leaving the lap, and a 5 represented the child not moving their hands from the lap at all during the task where

Children displayed the full range of behaviors from zero to five [*M* (*SD*) = 1.77 (1.79)]. The independent coders obtained good reliability on 15% of the total videos ($\kappa = .99$).

Model Building Task. Before the start of the study, the child was randomly assigned to either an unfamiliar (i.e., with a female adult stranger) or a familiar (i.e., with the mother) condition for the Lego model building task. The mother or the female adult stranger was shown how to build this model in a separate room, while the child was completing the NIH cognitive battery. Following completion of the NIH battery, the child's mother or the female adult stranger entered the room and began modeling how to build either an ice-cream cone for the 3-year-old participants or an alligator for the 4- and 5-year-old participants using Lego blocks following a standardized script. The mother or the stranger was given a script to follow with pictures depicting each step of construction to reduce differences in the builder's familiarity with Lego model construction. After the stranger or mother demonstrated how to construct the model for the child, the stranger or mother presented the child with a clear bag full of the Lego pieces required to build the model, plus several other distractor pieces. This task was designed to elicit social support seeking from the children. Given the distractor pieces, it was expected that building the model would be challenging but possible for most children and that this difficulty would elicit direct or indirect social support seeking with the stranger or mother. The stranger or mother then told the child to make a model just like the one that had just been built for them. The mother and stranger were both instructed to do their best to allow the child to complete the model independently. The child was given a maximum of 15 minutes before the original female experimenter returned and praised the child for the model that was built.

Model Building Behavioral Coding. Computerized coding of behaviors during the building phase of the task was conducted using Behavioral Observation Research Interactive

Software (BORIS) (Friard & Gamba, 2016) by independent coders who were blind to the hypotheses of the study. Behaviors were only coded during the building phase and not during the teaching phase to minimize differences in the teaching style of the adult in the different conditions. BORIS allows for the assignment of keyboard buttons to specific behaviors so coders can turn a behavior "on" and "off" to capture the number of seconds children spent engaging in a behavior. The videos were coded for positive affect (smiling, laughing, joking), asking for help (verbally requesting help, seeking proximity, touching), gaze towards the mother or stranger to capture social support seeking, and persistence (on-task building behavior). These behaviors were not mutually exclusive. For example, children could be working on the task while asking for help and displaying positive affect. Acceptable to excellent interrater reliability was established on 10% of the videos for positive affect ($\kappa = .68$), asking for help ($\kappa = .98$), gaze ($\kappa = .98$), and persistence ($\kappa = .99$). To account for differences in the amount of time taken to build the Lego model, a proportion score for each behavior was created by dividing the total number of seconds spent engaging in each of the aforementioned behaviors by the total building task time.

Composite Measures

Inhibitory Control Composite. An inhibitory control composite score was derived from parental report and performance on the dinky toys and Flanker tasks. A confirmatory factor analysis supporting the use of a composite of inhibitory control using these three indicators has been previously published in a separate paper examining the curvilinear relation between inhibitory control and avoidant social behaviors with an unfamiliar peer (Hassan & Schmidt, 2021b). Given the inclusion of a 3-way interaction in the present study, and because of our relatively limited sample size, we elected to use an observed rather than latent variable of inhibitory control to conserve power. All three variables were significantly, positively correlated

(*r*s > .17, *p*s < .045), and so scores for all three measures were *z*-scored and summed. Higher values on this composite represented relatively higher levels of inhibitory control.

Social Support Seeking Composite. A social support seeking composite score was derived from children's scores of positive affect, asking for help, and gaze towards the mother or stranger. All three variables were significantly, positively correlated (*r*s > .24, *p*s < .004), and so all three scores were *z*-scored and summed. Higher values on this composite represented relatively higher levels of social support seeking.

Statistical Analyses

We used a one-way between-subjects analysis of covariances (ANCOVAs) to determine whether there was equality of shyness and inhibitory control across the familiar and unfamiliar conditions and whether there were mean-level differences in social support seeking and persistence across the conditions, controlling for children's age and sex. To determine whether the interaction between shyness and inhibitory control in predicting social support seeking and persistence depended on contextual familiarity, we used a multiple linear regression, including the main effects of shyness, familiarity condition, and inhibitory control, the three two-way interactions (i.e., shyness x familiarity condition, shyness x inhibitory control, and familiarity condition x inhibitory control), and the single three-way interaction (i.e., shyness x familiarity condition x inhibitory control), controlling for children's age and sex. The dependent measure was either social support seeking or persistence. All analyses were conducted in SPSS version 26. The data supporting the findings reported below are available upon reasonable request. The study was not preregistered.

Sample Size Calculation

The sample size was determined by conducting a power analysis in G*Power for linear regression (Faul et al., 2007). Although no study, to our knowledge, has examined the three-way interaction among shyness self-regulation, and a binary third variable, we used the average effect size ($f^2 = 0.40$) from three previous studies that examined the moderating role of self-regulation in the relation between shyness and socioemotional outcomes and that reported effect sizes (Henderson, 2010; Poole et al., 2021; Sette et al., 2018). This power analysis revealed that for our objective of examining the two-way interaction between shyness and inhibitory control in predicting social behavior, we would require a minimum sample size of 35 participants (Power = 0.80, $\alpha = 0.05$). Given that the three-way interaction including shyness, inhibitory control, and the binary variable depicting context will be decomposed into two two-way interactions between shyness and inhibitory control in the familiar and unfamiliar context, we noted that a minimum sample size of 35 participants per context would be required. After imputation (described below), we were therefore adequately powered with 83 children in the familiar condition and 84 children in the unfamiliar condition.

Missing Data

Of the 167 children, 3 were missing data on the shyness measure, 17 were missing data on the inhibitory control composite measure, 10 were missing data on the social support seeking mease, and 6 were missing data on the persistence measure. Because some children overlapped on missing data for the variables of interest, there were a total of 138 children with complete data. Reasons for missing data included children refusing to complete the visit, parents failing to complete the questionnaire, children not passing the teaching phase of the Flanker task, video recording software technical difficulties, or outlier scores (i.e., > 3 *SDs* above or below the mean) on measures of inhibitory control, social support seeking, or persistence. Children with

missing data on at least one variable did not differ from children with complete data based on sex, χ^2 (1) = 0.60, p = .439, maternal education level, t(164) = -0.81, p = .417, or household income, t(147) = -0.97 p = .335. However, missingness was associated with mean-level differences in age, t(165) = -2.32, p = .022, such that children with missing data on at least one variable (M_{age} = 3.75 years, SD_{age} = .0.61 years) were significantly younger than children with complete data (M_{age} = 4.11 years, SD_{age} = 0.78 years).

Little's test of Missing Completely at Random (MCAR) was not significant, χ2 581.71, *df* = 482, p = .12, suggesting that patterns of missing data did not violate the assumption that data were missing completely at random. To leverage the complete sample (N = 167) and avoid the biased parameter estimates that can occur with pairwise or listwise deletion missing data were imputed using the expectation-maximization algorithm (Schafer & Graham, 2002).

Results

Descriptive Statistics

Table 4.1 depicts the means, standard deviations, ranges, and intercorrelations among study variables separately for the familiar and unfamiliar condition. Of note, shyness was significantly positively correlated with persistence in the unfamiliar (r = .30, p = .036) and familiar (r = .23, p = .034) condition. Social support seeking was positively correlated with persistence only in the familiar condition (r = .35, p = .001).

Preliminary Analyses

To ensure that there was equality across conditions in shyness and inhibitory control, we used two separate one-way ANCOVAs with familiarity condition as the between-subjects factor, with shyness and inhibitory control as the dependent measures, and children's age and sex as covariates. We found that there were no mean level differences in shyness, F(1, 163) = 0.15, p =

.705, $\eta^2 = .001$ or inhibitory control, $F(1, 133) = 0.08$, $p = .776$, $\eta^2 = .001$, across familiarity conditions.

To determine whether there was a main effect of contextual familiarity on children's social support seeking and persistence, we used two separate one-way ANCOVAs, with familiarity condition as the between-subjects factor, social support seeking and persistence as the dependent measure, and children's age and sex as covariates. We found a significant effect of familiarity condition on children's social support seeking, $F(1, 163) = 18.92$, $p < .001$, $\eta^2 = .104$, where children engaged more with their mother ($M = 0.73$, $SE = 0.24$) than with the stranger ($M = -0.72$, $SE = 0.23$). There were no mean level differences in persistence across familiarity contexts, $F(1, 163) = 0.54$, $p = .465$, $\eta^2 = .003$, suggesting that children were equally likely to spend time trying to build the model with their mother and the stranger.

Shyness x Inhibitory Control x Context Familiarity Interaction in Predicting Social Support Seeking

To determine whether the interaction between shyness and inhibitory control in predicting social support seeking depended on contextual familiarity, we used a multiple linear regression, controlling for children's age and sex. The complete model was statistically significant, $F(9, 157) = 5.62$, $p < .001$, and accounted for 24% of the variance in social support seeking. We found a significant three-way interaction among shyness, familiarity condition, and inhibitory control ($\beta = 0.45$, $p < .001$). Figure 4.1 depicts this interaction visually, and Table 4.2 presents the statistical information for the complete model.

To interpret the three-way interaction, we conducted simple slopes analyses where we examined the relation between shyness and social support seeking at low and high values of inhibitory control separately in the familiar and unfamiliar contexts (Aiken & West, 1991;

Dawson & Richter, 2006). Consistent with predictions made by the risk potentiation model of control, when children were in the presence of a stranger in the unfamiliar context, shyness was negatively associated with observed social support seeking at relatively high levels of inhibitory control (β = -0.56, p = .041) and unrelated to social support seeking at relatively low levels of inhibitory control (β = -0.30, p = .240). In contrast, when children were in the presence of their mother in the familiar context, shyness was positively associated with social support seeking at relatively high levels of inhibitory control (β = 0.53, p = .009), and unrelated to social support seeking at relatively low levels of inhibitory control (β = -0.40, p =.093).

To further interpret the results of the three-way interaction, we also conducted slope differences tests following recommendations reported elsewhere (Dawson & Richter, 2006). The difference between the slopes depicting the relation between shyness and social support seeking were not significantly different in the familiar, high inhibitory control context and the unfamiliar, low inhibitory control context, t = 0.72, p = .474. Similarly, the difference between the slopes depicting the relation between shyness and social support seeking in the familiar, low inhibitory control context and the unfamiliar, high inhibitory control context were non-significant, t = -0.45, p = .651. The difference between the slopes depicting the relation between shyness and social support seeking in the familiar and unfamiliar low inhibitory control contexts was just above statistical significance, t = -1.20, p = .051. All other slopes were significantly different from each other (ps ≤ .025).

Shyness x Inhibitory Control x Context Familiarity Interaction in Predicting Persistence

We also examined if shyness, inhibitory control, and contextual familiarity predicted persistence in working on the building task. The complete model was statistically significant, $F(9, 157) = 6.03$, $p < .001$, and accounted for 27% of the variance in persistence. However, the

three-way interaction among shyness, familiarity condition, and inhibitory control was not statistically significant (β = 0.01, p = .981). Table 4.3 presents the statistical information for the complete model.

Discussion

We examined whether the risk potentiation model of cognitive control depended on contextual familiarity (Henderson et al., 2015; Henderson & Wilson, 2017). More specifically, we examined whether the moderating role of inhibitory control on the relation between shyness and observed social support seeking differed during a building task with their mom (i.e., a familiar context) versus a novel adult female research assistant (i.e., an unfamiliar context). We found a three-way interaction among shyness, familiarity condition, and inhibitory control in predicting social support seeking, but not task persistence. In the unfamiliar condition, we found that shyness was negatively associated with social support seeking at high levels of inhibitory control in keeping with the risk potentiation model of control (Henderson et al., 2015; Henderson & Wilson, 2017). In the familiar condition, we found that shyness was positively associated with social support seeking at high levels of inhibitory control. We also found that these results were specific to social support seeking, as the interaction three-way interaction among shyness, inhibitory control, and familiarity was not related to persistence during the model building task. These results suggest that the "double-edged sword" of inhibitory control on social behavior may depend on both temperamental style *and* contextual familiarity.

Across the sample, we found that children exhibited higher levels of social support seeking with their mother compared with an unfamiliar research assistant. Stranger wariness appears to first emerge in infancy (Brooker et al., 2013; Waters et al., 1975). Although infants and toddlers appear to display higher levels of stranger wariness (operationalized as lower levels

of social support seeking) than preschool-aged children (e.g., Greenberg & Marvin, 1982), preschool-aged children still exhibit social wariness. It is important to note, however, that the level of wariness may be influenced by individual differences in temperamental or physiological factors (K. A. Buss, 2011; K. A. Buss et al., 2013). Given the familiarity of mothers and the presumably frequent interactions preschoolers have with them, higher levels of social support seeking with mothers compared to a novel research assistant likely reflect higher levels of familiarity and comfort in response to mother and potential stranger wariness in response to the research assistant. In other words, these results are likely indicative of developmentally appropriate and expected wariness towards a stranger.

In the unfamiliar condition, we found that shyness was negatively associated with social support seeking at high levels of inhibitory control, and unrelated to social support seeking at low levels of inhibitory control. These results are in line with previous studies that have examined the moderating role of a physiological or behavioral index of inhibitory control in the relation between shyness or related constructs and various psychosocial outcomes (Brooker et al., 2016; Henderson, 2010; Lahat et al., 2014; Lamm et al., 2014; Poole et al., 2021; Sette et al., 2018; Thorell et al., 2004; Troller-Renfree et al., 2019; White et al., 2011). Together, these studies converge with our findings to suggest that, at least in an unfamiliar context, higher levels of inhibitory control interfere with more positive socioemotional and psychological outcomes, and in this case, observed social support seeking.

Of note, the slope difference test revealed that the relation between shyness and social support seeking was the same when children were in the unfamiliar condition and had relatively high inhibitory control and when the children were in the familiar condition and had relatively low inhibitory control. Similarly, the relation between shyness and social support seeking was

the same when children were in the familiar condition and had relatively high inhibitory control and when the children were in the unfamiliar condition and had relatively low inhibitory control. The equivalence between these slopes at different levels of inhibitory control and contextual familiarity further supports the assertion that the moderating role of inhibitory control in the relation between shyness and social support seeking depends on the familiarity of social partners.

One unique contribution of the present study is the inclusion of a familiar context to examine whether the risk potentiation model of control functions similarly in an unfamiliar and familiar context. In contrast to the results in the unfamiliar condition and predictions made by the risk potentiation model of control (Henderson et al., 2015; Henderson & Wilson, 2017), we found that shyness was positively associated with social support seeking at relatively high levels of inhibitory control in the familiar context. In this context, inhibitory control positively impacted shy children's social support seeking. Inhibitory control includes the ability to keep rules and a goal in mind and the ability to monitor and modify behavior in support of that goal. In the model building context, the goal is to replicate the model that was built by the adult. In the familiar context without the fear associated with social novelty, these processes associated with inhibitory control may facilitate social support seeking for the shy child to elicit support from the mother so that the child can achieve their goal of completing the task. Here, this may be more relevant for shy children rather than non-shy children because shy children may recall that the main research assistant will return and see what the child has built, and the shy child may be concerned about the negative evaluation of their performance. Of note, we are framing social support seeking positively during the building phase because the task was designed to be challenging for children, so seeking support, smiling, and gazing toward the mother or unfamiliar experimenter were considered developmentally appropriate behaviors in this context. These

results are consistent with studies that have examined the influence of self-regulation more broadly (Eisenberg et al., 2009, 2010; Graziano et al., 2007; Ponitz et al., 2009; Wilson, 2003), outside of reactive temperamental styles, on children's socioemotional outcomes, and suggest that the risk potentiation model of control may be context-specific. Further, because the three-way interaction among shyness, inhibitory control, and familiarity context was not a statistically significant predictor of persistence during the building task, our results appear to be specific to *social* behaviors rather than task behaviors.

In the first paper to formally introduce the risk potentiation model of cognitive control, Henderson and colleagues (2015) reviewed another model that can be used to make predictions about the influence and interaction of reactive (i.e., shyness) and controlled (e.g., inhibitory control) processes on the development risk for psychological and socioemotional problems. The "overgeneralized control model" proposes that the automatic response biases observed in individuals with reactive temperamental styles lead to overgeneralized orienting responses in addition to the activation of controlled processes in unnecessary contexts. Through associative learning, this process may lead to inappropriate use of controlled processes and overgeneralized mode of automatic orientating in contexts that do not call for these responses (i.e., overgeneralization). The differences we observed in the adaptiveness of inhibitory control depending on a familiar versus unfamiliar context challenge this hypothesis. Although the present study cannot directly test whether shy children can differentiate between low and high-threat contexts, our results do suggest that, at minimum, the interaction of shyness and inhibitory control on children's social support seeking was not completely overgeneralized and does appear to depend on context.

Strengths, Limitations, and Future Directions

The present study had several strengths, including the use of a relatively large sample and the extension of a burgeoning contemporary developmental theory of shyness and self-regulation (Brooker et al., 2016; Hassan et al., 2020; Henderson, 2010; Henderson et al., 2015; Henderson & Wilson, 2017; Lahat et al., 2014; Lamm et al., 2014; Poole et al., 2021; Sette et al., 2018; White et al., 2011) to different contexts using a between-subjects design experimentally manipulating contextual familiarity, and the use various indices of inhibitory control and observed social behavior. However, notwithstanding these strengths, the results should be interpreted within their limitations.

First, shyness was parentally reported rather than directly observed, so the responses may have been subject to bias. However, the questionnaire we used in the present study to measure shyness is widely used and known to be reliable (Rothbart et al., 2001). Second, our sample was primarily White, and the mean household income was relatively high, so our results may not be generalizable to children from more socioeconomically disadvantaged homes and ethnically diverse backgrounds. Third, although conducting the study in a laboratory setting with a structured building task may be considered a strength because we had control over construct operationalization and consistent procedures across the different experimental conditions, there is a natural trade-off between the control we have in the laboratory and ecological validity. As such, it will be important to replicate the results from the present study using different conceptualizations of familiarity in the classroom, the child's everyday environment outside of the classroom, or in the laboratory with children's peers and with less structured social engagement tasks to increase ecological validity. It would also be helpful to replicate these results using behavioral observations of shyness in a more ethnically and socioemotionally

diverse sample of preschoolers, using a longitudinal design in multiple contexts to chart the developmental course of these processes in different contexts.

Conclusions and Implications

The goal of the present study was to test the risk potentiation model of cognitive control in different contexts. In an unfamiliar context, shyness was only negatively associated with social support seeking at relatively high levels of inhibitory control, consistent with the risk potentiation model of control. In a familiar context, shyness was only positively associated with social support seeking at relatively high levels of inhibitory control. This three-way interaction was not related to differences in children's persistence during the model-building task.

The present findings have implications for theory. Theoretically, our results provide support for the risk potentiation model in unfamiliar contexts and suggest that familiarity reduces the negative impact of inhibitory control in the context of shyness (Henderson et al., 2015; Henderson & Wilson, 2017). It also challenges the overgeneralized control model because the impact of inhibitory control on the shy-social support seeking relation was not the same across contexts (Henderson et al., 2015). The present results need replication, and if successfully replicated, we could infer that the negative impact of inhibitory control for shy children is influenced by modifiable contextual factors rather than instantiated processing patterns (i.e., dispositional, temperamental) that occur across contexts. Further, the present study also provides support for heterogeneity in both shyness and self-regulation by demonstrating that 1) shyness is not always associated with lower levels of social support seeking, 2) social support seeking may depend on both inhibitory control and context, and 3) inhibitory control can be facilitative or interfere with social support seeking depending on both temperament and context.

The present study also has practical implications. The preschool period is an important developmental time because self-regulation is rapidly developing (Dennis et al., 2007; Geeraerts et al., 2021; Klenberg et al., 2001; Kochanska et al., 1996; Schoemaker et al., 2014; Williams et al., 1999), and children have yet to enter formal schooling. Although school entry can be an exciting time for many children, there is some evidence suggesting that it may be particularly difficult for shy children (Coplan et al., 2008). This is not surprising because shy children display wariness and fear in the context of social novelty (A. H. Buss, 1986; Cheek & Buss, 1981; Karevold et al., 2012; Sanson, 1996), and school entry is marked by new people and social situations. Given sufficient replication across different contexts, the results from the present study suggest that increasing contextual familiarity may increase the likelihood that shy children with relatively high levels of inhibitory control will engage with their social environment. This knowledge can be then used to help set shy children on a positive socioemotional trajectory.

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Table 4.1

Pearson's Correlations, Mean, Standard deviation (SD), and Range for Study Measures Separated by Familiarity Condition

Variables	1	2	3	4	Mean (*SD*) Unfamiliar	Range Unfamiliar	Mean (*SD*) Familiar	Range Familiar
1. Shyness	–	-.01	-.02	.30*	3.47 (1.24)	1.17 to 6.67	3.40 (1.20)	1 to 6
2. Inhibitory control	-.03	–	-.05	-.14	-0.07 (1.84)	-3.47 to 4.06	0.07 (2.20)	-5.42 to 5.03
3. Social support seeking	.11	-.03	–	-.03	-0.71 (2.20)	-2.42 to 12.86	0.72 (2.23)	-2.42 to 7.98
4. Persistence	.23*	-.07	.35**	–	49.50 (9.67)	9.36 to 71.76	48.05 (12.79)	8.36 to 82.87

Note. Intercorrelations among study variables for the unfamiliar condition and familiar condition fall above and below the midline, respectively.

*$p < .05$ **$p < .01$

Table 4.2

Three-way Interaction among Shyness, Inhibitory Control, and Familiarity Condition in Predicting Social Support Seeking during a Toy Building Task, Controlling for Children's Age and Sex

Predictor	Unstandardized Beta	*SE*	Standardized Beta	R^2	*P*
Step 1				.08	
Age	-0.78	0.23	-.26		<.001
Sex	-.49	0.35	-.11		.165
Step 2				.17	
Age	-0.79	0.22	-0.26		<.001
Sex	-0.41	0.34	-0.09		.227
Shyness	0.02	0.13	0.01		.893
Inhibitory Control	-0.01	0.09	-0.01		.887
Familiarity Context	1.44	0.33	0.31		<.001
Step 3				.18	

Age	-0.81	0.22	-0.26	<.001
Sex	-0.39	0.35	-.08	.263
Shyness	-0.28	0.43	-.15	.514
Inhibitory Control	-0.27	0.33	-.24	.413
Familiarity Context	0.77	0.98	.17	.433
Shyness*Inhibitory Control	0.06	0.06	.20	.309
Shyness*Familiarity Context	0.19	0.27	.22	.475
Inhibitory Control* Familiarity Context	0.03	0.17	.05	.845
Step 4			.24	
Age	-0.81	0.21	-0.27	<.001
Sex	-0.38	0.34	-0.82	.259
Shyness	-0.32	0.42	-0.17	.437
Inhibitory Control	2.11	0.73	1.82	.005
Familiarity Context	-0.66	0.21	-0.17	.415
Shyness*Inhibitory Control	-0.66	0.26	-2.10	.002
Shyness*Familiarity Context	0.19	0.26	0.22	.461

Inhibitory Control* Familiarity Context	-1.43	-.44	-2.07	.001
Shyness*Familiarity Context*Inhibitory Control	0.44	0.12	2.37	<.001

Note. Females coded as 1, males coded as 2; Unfamiliar condition coded as 1, familiar condition coded as 2

Table 4.3

Three-way Interaction among Shyness, Inhibitory Control, and Familiarity Condition in Predicting Persistence during a Model Building Task, Controlling for Children's Age and Sex

Predictor	Unstandardized Beta	*SE*	Standardized Beta	R^2	*p*
Step 1				.21	
Age	-6.80	1.02	-0.46		<.001
Sex	0.49	1.57	0.02		.754
Step 2				.25	
Age	-6.43	1.03	-0.44		<.001
Sex	0.76	1.58	0.03		.634
Shyness	1.66	0.62	0.19		.008
Inhibitory Control	-0.12	0.40	-0.02		.764
Familiarity Context	-1.02	1.54	-0.05		.512

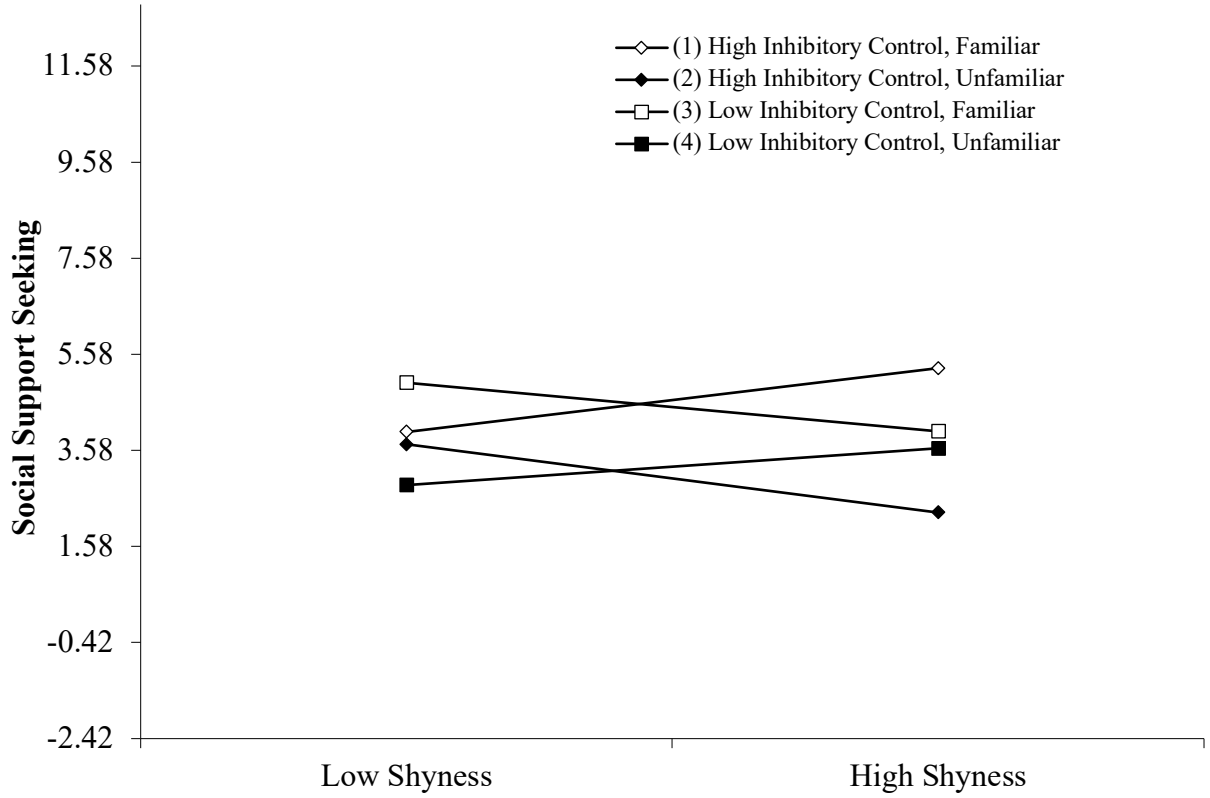
Step 3				.26
Age	-6.51	1.04	-0.44	<.001
Sex	0.93	1.61	0.04	.565
Shyness	0.22	2.00	0.03	.911
Inhibitory Control	-1.52	1.55	-0.27	.328
Familiarity Context	-4.22	4.56	-0.19	.356
Shyness*Inhibitory Control	0.17	0.29	0.11	.546
Shyness*Familiarity Context	0.93	1.26	.22	.458
Inhibitory Control* Familiarity Context	0.52	0.78	0.16	.505
Step 4				.26
Age	-6.51	1.04	-0.44	<.001
Sex	0.93	1.62	0.04	.566
Shyness	0.22	2.00	0.03	.912
Inhibitory Control	-1.44	3.54	-0.26	.684
Familiarity Context	-4.22	4.57	-0.19	.358
Shyness*Inhibitory Control	0.15	1.01	0.10	.883

Shyness*Familiarity Context	0.93	1.26	0.22	.460
Inhibitory Control* Familiarity Context	0.48	2.11	0.14	.822
Shyness*Familiarity Context*Inhibitory Control	0.01	0.59	0.02	.981

Note. Females coded as 1, males coded as 2; Unfamiliar condition coded as 1, familiar condition coded as 2

Figure 4.1

Interaction of Shyness, Familiarity Context, and Inhibitory Control in Predicting Social Support Seeking during a Toy Building Task



Note. Values are plotted at one (unfamiliar condition) and two (familiar condition) and one standard deviation above and below the mean of inhibitory control. Slopes 1 and 2 are statistically significant.

CHAPTER 6

General Discussion

Summary of Findings

The goal of this dissertation was to examine the contexts in which self-regulatory processes act as a resiliency and risk factor during infancy and the preschool period. Using a longitudinal framework, I first examined the relation between infants' regulatory capacity and prospective problem behaviors as moderated by physiological regulation in the face of an emotionally salient stressor (Chapter 2). Guided by longstanding theoretical models challenging the "more is better" approach to self-regulation (Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992), I then examined the curvilinear relation between inhibitory control, avoidant social behavior, and mental health difficulties prospectively across the preschool period (Chapter 3). Finally, I used the risk potentiation model of control (Henderson et al., 2015; Henderson & Wilson, 2017) as a guiding framework to examine the moderating role of inhibitory control on the relation between shyness and 1) actor and partner's observed social behavior with an unfamiliar peer (Chapter 4), and 2) observed social behavior in a familiar versus unfamiliar context (Chapter 5) in preschoolers. Collectively, these studies suggest that self-regulatory processes do not always act as a resiliency factor, and that physiological, temperamental, social, and contextual factors may modify the adaptiveness of some aspects of temperamental self-regulation.

Guided by the lack of work integrating trait and state regulation in infancy, in Chapter 2, I examined whether cardiac vagal regulation during an emotionally salient stressor (Tronick et al., 1978) at 8 months moderated the association between maternal report of infant regulatory

capacity at 8 months and behavior problems at 14 months. Infants' trait regulatory capacity was only negatively associated with behavior problems at relatively high levels of physiological regulation.

These results were interpreted in the context of Polyvagal Theory (Porges, 1995, 2007). Given the emotionally salient and psychologically threatening nature of the context in which physiological regulation was recorded, I speculated that physiological regulation may reflect effective emotion regulation and a physiological preparedness to cope with the environmental demands of the stressor. These results suggest that starting in infancy, temperamental regulation is not indiscriminately protective, and the resiliency associated with temperamental regulation may sometimes depend on state-related processes such as physiological regulation.

In Chapter 3, I empirically evaluated theoretical frameworks suggesting that too little *and* too much self-regulation would have negative social and psychological consequences for children (Block & Block, 1980; Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992). I found that inhibitory control displayed a U-shaped relation with observed avoidant social behavior with an unfamiliar peer and maternal report of internalizing and externalizing difficulties, where relatively low and high levels of inhibitory control were related to the highest levels of avoidant social behavior and mental health difficulties. These findings extended the results of Chapter 2 by focusing on one facet of temperamental self-regulation during the preschool period and complement Study 1 by suggesting that higher inhibitory control is not necessarily protective, and that both over and underregulation can have negative social and psychological consequences for children. I speculated that intermediate levels of inhibitory control may promote flexibility, which may facilitate less avoidant social behavior and resiliency against mental health difficulties.

In Chapters 4 and 5, I extended previous work providing support for the risk potentiation model of control in a social context with a new peer (Chapter 4) and with a familiar versus unfamiliar social partner (Chapter 5). In Chapter 4, I found that the interaction between shyness and inhibitory control in predicting observed social behavior differed based on whether the child's own behavior (actor effects) or the other child's behavior (partner effects) was the focus of the analysis. Consistent with the risk potentiation model of control, when inhibitory control was high, shyness was negatively associated with observed approach behavior with an unfamiliar peer. When inhibitory control was low, shyness was not associated with observed approach behavior. When inhibitory control was high, shyness was also negatively associated with the partner's observed avoidance behavior. When inhibitory control was low, shyness was positively associated the partner's observed avoidance behavior. The actor effects observed in Chapter 4 were in line with previous studies, suggesting that shyness and more reactive temperamental styles may be associated with social and psychological difficulties when inhibitory control is high (Henderson, 2010; Lahat et al., 2014; Lamm et al., 2014; Poole et al., 2021; Rodrigues et al., 2021; Sette et al., 2018; Thorell et al., 2004; Troller-Renfree et al., 2019; L. K. White et al., 2011). I speculated that shy and overcontrolled children may not benefit from the lower levels of partner avoidance observed in the present study because of their developmental history of experiencing social fear, and then having that fear perpetuated rather than regulated. Chapter 4 demonstrated the importance of attending to both actor and partner effects to gather a more complete picture of children's social behavior.

In Chapter 5, I examined whether the predictions made by the risk potentiation model of control would generalize to both an unfamiliar and familiar context. In the unfamiliar condition, I found that shyness was negatively associated with social support seeking at high levels of

inhibitory control, and unrelated to social support seeking at low levels of inhibitory control. In the familiar condition, however, I found that shyness was positively associated with social support seeking at relatively high levels of inhibitory control, and unrelated to social support seeking at relatively low levels of inhibitory control. I speculated that the negative impact of inhibitory control on shy children's social support seeking may depend on social familiarity, given shy children's presumed sensitivity to social novelty (Buss, 1986; Cheek & Buss, 1981; Karevold et al., 2012; Sanson, 1996). This is an especially important contribution because familiarity is a modifiable factor and can be manipulated to support shy children in new social situations.

Strengths, Limitations, Considerations, and Future Directions

The series of studies comprising this dissertation collectively had several strengths worth noting, including the use of both cross-sectional and longitudinal designs, the inclusion of behavioral, cognitive, physiological, and parent reported measures, and a theoretically driven series of questions related to self-regulation. The series of studies comprising this dissertation should be collectively interpreted within the context of their limitations. The participants within each of the four studies were socioeconomically and racially homogenous. Socioeconomic status, as indexed by maternal education (Chapter 2) and household income (Chapters 3 to 5), was high. The sample was also primarily White in Chapters 3 to 5, and ethnicity was not collected in Chapter 2. A lack of socioeconomic and racial diversity is a limitation because it impacts the generalizability of the results. For example, relations between effortful control and internalizing and externalizing difficulties have differed previously based on preschoolers' race (Choe, 2021), and socioeconomic status has been associated with differences in inhibitory control trajectories (Moilanen et al., 2010).

Second, although we employed a longitudinal approach in Chapters 2 to 4, we cannot establish temporal precedence between variables of interest because the variables were only measured at a single timepoint. For example, physiological regulation was only measured at Time 1 in Chapter 2, and observed social behavior was only measured at Time 2 in Chapters 3 and 4.

Third, although the retention was excellent in Chapter 2, the number of participants lost to follow-up in Chapters 3 and 4 was relatively high. This was in part due to difficulties aligning the schedules of the families of sex-matched children at Time 2 that were tested at Time 1 approximately 1.5 years before the dyadic visit. Importantly, missingness in all studies was not associated with any variables of interest or sociodemographic information at Time 1, patterns of missingness did not violate the assumption that data were missing completely at random, and we used imputation methods recommended for reducing bias compared to listwise deletion (Schafer & Graham, 2002).

Finally, although we moved beyond parent report to observed social behavior in service of increasing ecological validity in Chapters 3 to 5, social behavior was still measured in a laboratory context. As a result, our findings may not generalize to contexts outside of the laboratory when children are interacting with their peers and adults, for example, in the school setting.

Future studies should examine relations between self-regulation, shyness, and social behavior in settings like the school and in the home and in unfamiliar contexts outside of the laboratory with a more socioeconomically and ethnically diverse sample to replicate our results and improve the generalizability of our findings. Future work should also measure variables of

interest across time points longitudinally and use statistical approaches like cross-lagged analyses to establish temporal precedence and directionality.

Implications and Conclusions

The findings from this dissertation have theoretical and practical implications. Self-regulation is most often framed as a temperamental factor that promotes resiliency because it works to modulate negative emotionality (Rothbart et al., 2003; Rothbart & Bates, 2006). Beyond this theoretical framework, temperamental regulation has indeed been associated with positive outcomes across domains (Aram et al., 2014; Blair & Razza, 2007; Diener & Kim, 2004; Eisenberg, 2010; Eisenberg et al., 1995, 1997, 2009; Gartstein et al., 2012, 2016; Kochanska et al., 2000; Kochanska & Aksan, 2006; Krueger et al., 1996; McClelland et al., 2007; Olson et al., 2005; Petitclerc et al., 2015; Ponitz et al., 2009; Rapport et al., 1986; Rothbart et al., 2001; St Clair-Thompson & Gathercole, 2006; B. A. White et al., 2013; Wittig & Rodriguez, 2019). The positive framing of self-regulation occurs because most of these studies examined direct relations between self-regulation and various outcomes and employed a linear analytical approach.

Theoretically, each of the four empirical chapters in this dissertation challenge the longstanding notion that self-regulatory processes are always protective for all children all the time. In Chapter 2, I demonstrated that rudimentary regulatory capacity was only protective against behavior problems when infants displayed high levels of physiological regulation. In Chapter 3, I demonstrated that both low *and* high levels of inhibitory control were associated with high avoidant social behaviors and mental health difficulties in preschoolers. In Chapter 4, I demonstrated shyness was associated with less approach related behavior with an unfamiliar peer only at high levels of inhibitory control, and that these findings differed when examining the

social partner's behavior. In Chapter 5, I demonstrated that shyness was only negatively associated with social support seeking at high levels of inhibitory control with an unfamiliar adult, but that that these findings differed when the adult was familiar. Together, these results suggest that some aspects of temperamental self-regulation may act as both a risk and resiliency factor depending on physiological, temperamental, social, and contextual factors.

Given that some aspects of self-regulation may act as a risk or resiliency factor, the promotion of self-regulation as a panacea for children is not recommended. Rather, considering children's context and promoting flexibility may be a better goal than overcontrol in support of children's positive socioemotional development.

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