Temperament, attention, and the social world:

New empirical approaches to the study of shyness and attention in middle childhood

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Statement of Contributions

I am either the majority contributor or sole contributor to all of the work presented in this thesis. This includes Chapters 2 and 3 which are co-authored with my supervisor Dr. Heather Henderson, and Chapter 4 which is co-authored with my collaborator Linda Sosa-Hernandez and my supervisor Dr. Heather Henderson. Citations and information regarding the publication of these works can be found in their respective chapters.

Abstract

In order to navigate their social world, children must come prepared to flexibly attend to and shift between the many different aspects of an interaction. For temperamentally shy children, for whom the demands of everyday interactions may be particularly onerous, attention may be particularly critical in predicting their ability to connect with others and achieve positive social outcomes. The studies presented in this dissertation sought to develop new means of assessing the interplay between individual differences in temperament and attention in social contexts in order to better understand how to support the social development of shy children. Chapter 2 examined how 8-year-old children's ability to shift their attention in a hierarchical figures task varied as a function of shyness and the perception that one's performance would later be evaluated by peers. As shyness increased, children were slower to respond in the peer monitoring condition relative to the baseline condition, but these changes in response time were not accompanied by changes in accuracy. These results highlight that under social conditions, shy children's behaviour may be subtly impacted in a way that makes them slower or less efficient to act in line with their goals. Chapter 3 builds on these findings by exploring the fluidity of children's social behaviour using a novel index of social connection: conversational response time. Nine- to 11-year-old children were observed conversing with an unfamiliar same-aged peer in an unstructured dyadic context. Their communications and behaviours were later coded on the basis of their content and timing. Faster conversational response time was associated with higher ratings of social engagement in both children themselves and (marginally) in their partners. Moreover, as a child's own shyness increased, the conversational response times of their partner also increased. The findings from this study demonstrate how subtle changes in conversational response time underlie the quality of children's interactions and may thereby impact their ability to form new social relationships across development. Exploring new means of empirically studying children’s moment-to-moment subjective experiences, Chapter 4 examined 7- and 8-year-old children’s self-reports of mind wandering while keeping time with a metronome via keypress on a keyboard. Consistent with past adult findings, children were less accurate and more variable in their keypresses on trials preceding self-reports of mind wandering, supporting the validity of their reports. Additionally, parent reports of children’s self-regulation difficulties were predictive of children’s keypress behaviour, lending further support for its validity as a measure. Together, the findings from these studies build on existing theoretical work and lay the groundwork for future research that will ultimately serve to optimize the social development of shy and non-shy children alike.

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And finally, for providing me with years of unwavering support and guidance, I would like to thank my supervisor, Heather. Communicating emotional truths without falling back on hackneyed phrases and sentimental tropes is hard. So, as you read these closing lines, know they are true and real in their most literal form: Heather, I would never have been able to make it through this stage of my life with anyone but you as a mentor and friend. Thank you.

Dedication

To my mom and dad; theirs is the definition of unconditional love.

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Quote

I would have dressed myself
in red roof tile, in smoke,
to continue there, but invisible,
to attend everything, but at a distance,
to keep my own obscure identity
fastened to the rhythm of the spring.

Shyness, Pablo Neruda

Chapter One: General Introduction

A child's social world is dynamic. Consider the following scene:

Seven-year-old Tyler stands at the periphery of the play area in Mrs. Pike's second grade class. Another boy, Colin, is enrapt in the construction of an ambiguous Lego structure. Intrigued by Colin's work but cautious by nature, Tyler hovers momentarily before approaching.

TYLER: What's that?

COLIN: A castle.

TYLER: Can I help?

COLIN: Sure.

With his foot in the door, Tyler sits down and begins on a new tower for the castle. From the current state of the structure and Colin's passing comments on what he is building, Tyler tries to understand how he might fit himself into Colin's plans. Tyler glances sporadically at his peer, monitoring for any sign of concern or disapproval and cautiously coordinating his reaches for the pile of blocks so as not to interrupt Colin's own. As they work in tandem and their fortress grows, they update their plans and negotiate next steps in response to each other's additions.

This example highlights that under close inspection, even the most mundane social interaction can be seen to involve many "spinning plates"; children must readily shift between a variety of subtasks at a moment's notice and continually integrate new information to keep the interaction going smoothly. This is an ongoing process requiring flexible thinking, snap decision-making, and, in some cases, active self-monitoring and regulation to be navigated successfully. Failure to keep up with the flow of activities or to factor in one's partner's goals and perspective could quickly bring the interaction to a grinding halt. This is true whether a child is engaging in collaborative play, sustaining conversation with a new friend, resolving conflict with an old one, or maneuvering virtually any other social interaction. Notably, for children like Colin, attentionally navigating social interactions comes instinctively and effortlessly, while for those like Tyler, keeping the plates spinning is both emotionally arousing and cognitively taxing. Indeed, to succeed in a dynamic social world, children must themselves be flexible actors and interpreters of that world, a greater challenge for some children than for others.

Past work has identified important relations between trait differences in attention and children's later social outcomes (e.g., Fergusson et al., 1997; White et al., 2011). However, the exact *mechanism* underlying these relations is unclear. What is it about how children deploy and/or regulate their attention that leads some to struggle while others succeed? What specific cognitive processes or social experiences are impacted? My dissertation studies and broader program of research address this gap in our understanding at various levels, examining how children's attention is impacted by individual difference and social contextual factors. I also seek to develop new methods of studying children's attention as it is deployed both externally (to tasks and stimuli in the world around them) and internally (to their own thought processes, be they productive or distracting).

Attentional flexibility in social contexts: A theoretical model

At any given moment during an interaction, there are countless things a child could attend to. Some lie in the external world: Tyler could be focusing on his Lego blocks, or on Colin's expression, or on some other distracting stimulus in the room. At the same time, rather than looking outward, a child might attend to subjective internal phenomena: Tyler could be lost in thought planning a new parapet, ruminating on the reason for Colin's perplexed look, or absently daydreaming about his favorite cartoon. From moment-to-moment over the course of an interaction, children's attention may be pulled in many different directions.

An organizing framework is necessary to make sense of how children's distribution of attention between these many sources could predict the success of their interactions with others. To this end, we proposed a theoretical account of children's attention to social goals and their ability to respond flexibly to events and stimuli that distract from those goals (Henderson & Wilson, 2017; updated in Fox et al., 2021). Figure 1 presents the core ideas of this account in the form of a vector diagram depicting a child's attention allocation in a hypothetical social situation (such as the interaction between Tyler and Colin).

Central to our account is the idea that at any given moment during a social activity, there is a requisite level of attention one must maintain to the social goals shared with one's partner(s) for the interaction to proceed smoothly. For example, the failure to attend sufficiently to an ongoing conversation may result in miscommunication, awkwardness, hurt feelings, or even conflict. Or in the case of Tyler and Colin, struggling to keep up with the state of their Lego structure and each others' activities could quickly result in a creative disconnect, interrupting the fun and damaging the prospects for their emerging friendship. The attention necessary for the child to continue working towards and ultimately meet their social goals is represented by the horizontal gray bar at the top of Figure 1. The level of attention necessary to achieve one's social goals may vary dramatically from moment to moment, thereby demanding ongoing flexibility as one moves through an interaction.

Occasionally, unexpected or personally salient events might momentarily steal one's attention away from one's primary goals, such as when Tyler detects (what he interprets as) a judgmental look from Colin. In Figure 1, the detection of a salient event is represented by the vertical dashed line. Having noted this expression of negative affect in his peer, Tyler's attention

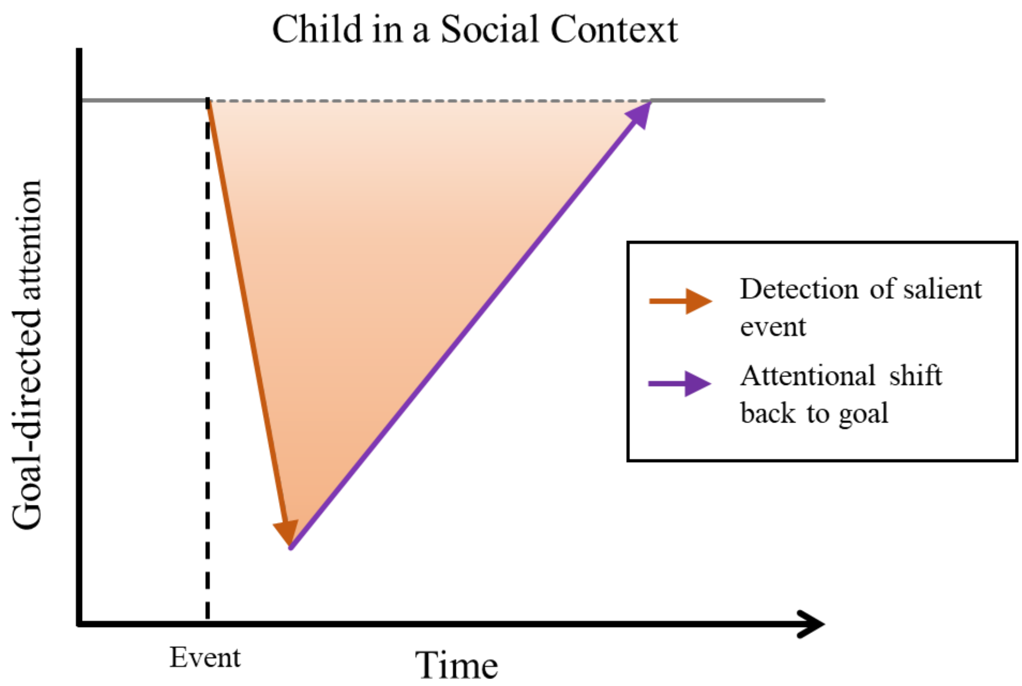

Figure 1. A hypothetical child's goal-directed attention in response to the detection of a salient event in a social context.

becomes glued to Colin's face, drawing his attention away from the Legos. This shifting in attention away from his primary goal-related activity (working on the castle) is represented by the orange arrow in Figure 1. Only after monitoring his peer's face for a short period and noting no further cause for concern is Tyler able to refocus his attention on the task at hand, reflected in the purple arrow in Figure 1.

Interpreting the relation between children's attention and the success of their interactions from the perspective of attention to social goals and response to distractors confers several advantages. First, this approach is highly useful for guiding empirical research, offering a clear framework for operationalizing behaviour and manipulating stimuli with regard to their relevance to intra- and interpersonal goals in that setting. This account is also agnostic with regard to how a child's attention may waver from their primary social goal; whether Tyler fixates on an external stimulus like his peer's face or becomes enrapt in an internal experience such as rumination, the key is the attentional deviation from the goal of engaging in fun block play with

Colin. As such, this framework can be applied to interpret children's behaviour across a wide variety of contexts, be they experimental or observational in nature. And critically, this account draws an important distinction between a) processes related to the *detection* of salient events that pull children's attention away from their social goals (orange arrow in Figure 1), and b) processes related to *shifting* attention back to their goal (purple arrow in Figure 1). Only by parsing children's behaviour into more granular processes can the specific mechanisms supporting or hindering children's social outcomes be identified, and accordingly, the individual differences giving rise to different patterns of behaviour.

The role of temperament in children's allocation of social attention

When seeking to explain the various ways in which children attend to and behave in social contexts, an important factor to consider is their underlying temperaments. While exact definitions vary, temperament broadly describes constitutional differences in the domains of emotion, attention, and activity levels that are relatively stable across time and circumstances, emerge early in life, and are thought to be rooted in biology (Bornstein et al., 2015; Chen & Schmidt, 2015; Rothbart et al., 2001). Temperament researcher Mary Rothbart characterizes temperament in terms of *reactivity*, describing children's reactions to changes in their surroundings, and *self-regulation*, describing processes that modulate these reactions (Rothbart & Derryberry, 1981; Rothbart et al., 2001). This distinction closely mirrors the processes of detection and shifting found in our account, thereby offering a clear path for mapping the relations between aspects of temperament and children's social attention.

One fundamental within-child factor underlying children's detection of salient social events, particularly when interacting with unfamiliar social partners, is their temperamental reactivity to novelty. From the first year of life, infants vary dramatically in how they respond to new objects, events, people, and challenges: while some children react with delight, others react with immediate distress (Kagan & Fox, 2006; White et al., 2011). Many infants in this latter group will go on to be identified as behaviourally inhibited (BI) in toddlerhood, a temperament characterized by negative emotions, freezing, and avoidance in the face of novel or unexpected events and stimuli (Fox et al., 2005; Kagan et al., 1984). Later in early and middle childhood, children who experience elevated anxiety and inhibition in unfamiliar *social* contexts are described as being temperamentally shy (Rubin, 2001; Buss, 1986). Shy children are particularly wary of situations in which they may be subject to social evaluation or exclusion, tending to withdraw and observe watchfully rather than involve themselves directly (Coplan et al., 1994; Henderson et al., 2004; Rubin & Coplan, 2004; Walker et al., 2014). This sensitivity to the perceptions of others increases as children move through middle childhood and early adolescence (Beidel & Alfano, 2011; Oh et al., 2008; Tang et al., 2017). Over the course of this period, children experience both rapid socio-cognitive development and a rapid expansion of their social networks through their engagement in formal schooling (e.g., Feiring & Lewis, 2017; Lalonde & Chandler, 2002; Selman, 1980).

Compared to other children, experimental work demonstrates children high in shyness and/or BI exhibit heightened reactivity to a wide range of socially salient phenomena. This includes increased physiological reactivity (e.g., startle responses) to novel sights and sounds, higher sensitivity to fearful and angry faces, and greater neurophysiological responses to performance feedback and the perpetration of errors (for a comprehensive summary, see Blackford et al., 2018; Fox et al., 2021).

Bringing these findings together, our account contends the detection any of these events or stimuli in a social context could draw a child’s attention away from their social goal, and critically, that the extent to which this detection interrupts a child's attention to their social goals varies as a function of their temperamental reactivity to social novelty. To illustrate this idea, a comparison of the goal-directed attention of a child high vs. low in shyness is presented in Figure 2. In the case of a child higher in shyness (such as Tyler), the detection of a salient event (e.g., a grumble of frustration from a peer) would absorb more of the child's attention and more significantly detract their attention from their ongoing task, as depicted by the orange arrow falling precipitously in the left panel of Figure 2. By contrast, in the case of a child with a more exuberant temperament (such as Colin), such an event would be less salient and accordingly would have less of an impact on his goal-directed attention, as depicted by the shorter orange arrow in the right panel of Figure 2. That is, all other things being equal, a child high in shyness or BI would have more of a "hole to dig themself out of" than would a child low in shyness or BI.

BI and temperamental shyness have been the subject of extensive research over the past half century, in large part due to its relations to social adjustment and well-being. BI is the single strongest predictor of whether a child will go on to develop social anxiety disorder, with 50% of children identified as high in BI going on to develop a disorder, amounting to a four- to sevenfold increase in risk relative to other children (Chronis-Tuscano et al., 2009; Clauss & Blackford, 2012). Our account contends temperamental differences in these instinctive detection processes that interrupt children's ability to focus on their social goals may play a significant role in this developmental relation. It is important to keep in mind, however, the other 50% of children high in BI who *do not* go on to develop a clinical disorder. The question then becomes:

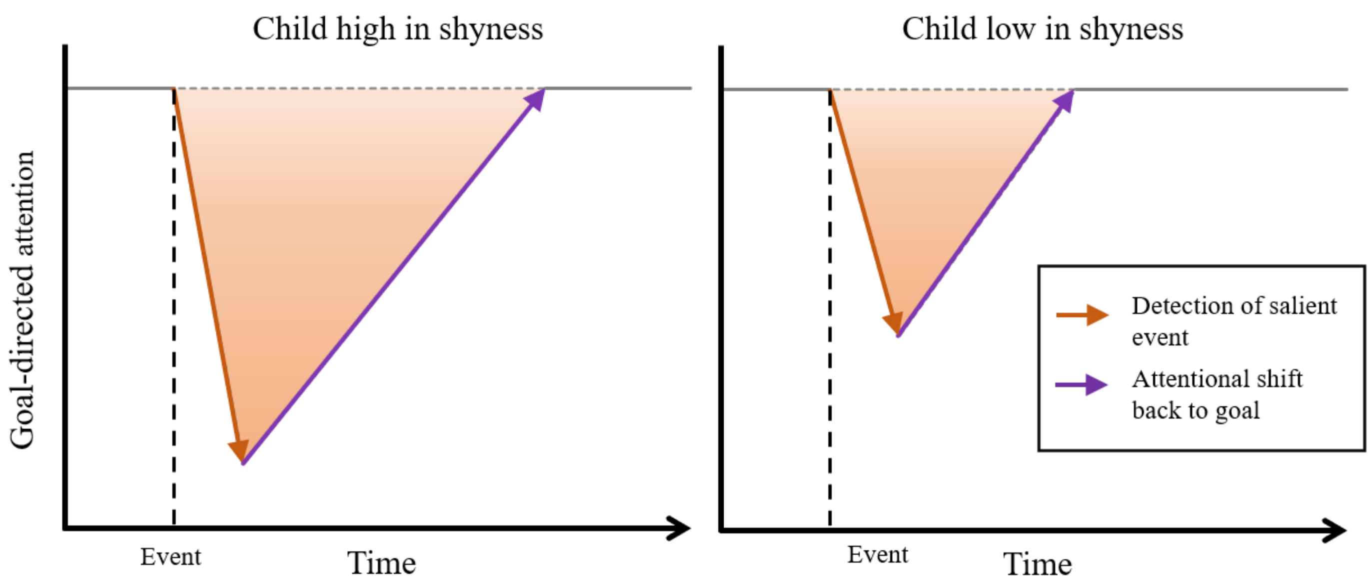

Figure 2. The goal-directed attention of a child high in shyness (left) vs. low in shyness (right) in response to the detection of a salient event in a social context.

what individual factors predict along which of these divergent trajectories a child high in BI will travel?

Our model offers a promising direction for exploring this question. As presented above, children's temperamental sensitivity to novel or unexpected events can "dig them a hole" attentionally. Touching on the second component of Rothbart's approach to studying temperament, the ability to actively *regulate* attention and flexibly shift back to one's primary goal may be a boon to children high in shyness/BI when interacting with peers, thereby protecting against socio-emotional difficulties over time.

The influence of executive functions in children's social development

Self-regulation, broadly defined, describes the ability to purposefully control one's attention and behaviour in order to achieve one's goals and meet the demands of one's environment (Baumeister & Heatherton, 1996; Hofmann et al., 2012). The development of self-regulation is a fundamental component of healthy development and is predictive of a host of positive outcomes including academic success, social fulfillment, stress tolerance, and resilience (Ayduk et al., 2000; Blair & Razza, 2007; Mischel et al., 1989; Ponitz et al., 2009). Central to the development of self-regulation is the development of executive functioning (EF), describing a group of related processes involved in the willful control and modulation of one's behaviour (Garon et al., 2008; Miyake et al., 2000).

A growing body of research suggests two components of EF are particularly important with regard to the developmental trajectories of children high in BI/shyness. The first, *inhibition*, describes the ability to deliberately override and prevent dominant, automatic, or prepotent responses in line with one's goals (Miyake et al., 2000). The second, known as *attention shifting* (or alternatively, *cognitive flexibility)*, describes the ability to flexibly shift between different tasks, perspectives, subgoals, and mental sets in order to facilitate the achievement of one's goals (Miyake et al., 2000).

Notably, an increasing body of evidence suggests these components of EF bear on the developmental outcomes of children high in BI *in opposite directions*. Specifically, attention shifting has been found to a protective factor in the prediction of social anxiety for children high in BI (Buzzell et al., 2021; Eggum-Wilkins et al., 2016; Eisenberg, 1998; Troller-Renfree et al., 2019a; White et al., 2011; Wolfe et al., 2014). By contrast, inhibition has been consistently identified as a risk factor for children high in BI, such that BI children who are adept at inhibiting their behaviour are more likely to go on to develop social anxiety (Buzzell et al., 2021; Eggum-Wilkins et al., 2016; Henderson, 2010; Troller-Renfree et al., 2019b; White et al., 2011). What is missing from our current understanding is the exact *mechanism* by which attention shifting and inhibition impact children's day-to-day functioning and accordingly their broader social outcomes.

With this gap in mind, our account contends that how a child characteristically balances the use of inhibition vs. attention shifting to regulate their attention in social contexts is central to the quality of their peer interactions, with a tendency toward the latter supporting more rewarding interactions over time. Ultimately, accumulating evidence from their past experiences comes to predict a child's perceptions of themselves and their relationships with others, and accordingly their likelihood of developing social anxiety. To illustrate how these two aspects of EF could differentially impact a child's behaviour during a peer interaction, Figure 3 presents hypothetical data from two children identical in their level of shyness but varying in their inhibition and attention shifting abilities (represented by the red and blue dashed arrows, respectively).

First, consider a child whose inhibition overshadows their attention shifting, depicted in the left panel of Figure 3 by a longer red relative to blue arrow. We propose that after the detection of a salient event, a stronger inclination toward inhibition over attention shifting would promote sustained vigilance toward the source of the detected event for further processing and monitoring. For example, after hearing Colin sigh in frustration, Tyler might stop what he was doing to fixate his attention on Colin's face, gathering additional information on his mood state, contemplating the cause of this expression, and/or bracing for further signs of negative affect. Whether the boys were playing with blocks or engaging in a conversation, the lengthy time it would take for Tyler to shift his attention back to the task at hand (represented by the purple arrow) could throw off the flow of their interaction and be perceived by Colin as awkward or uncomfortable.

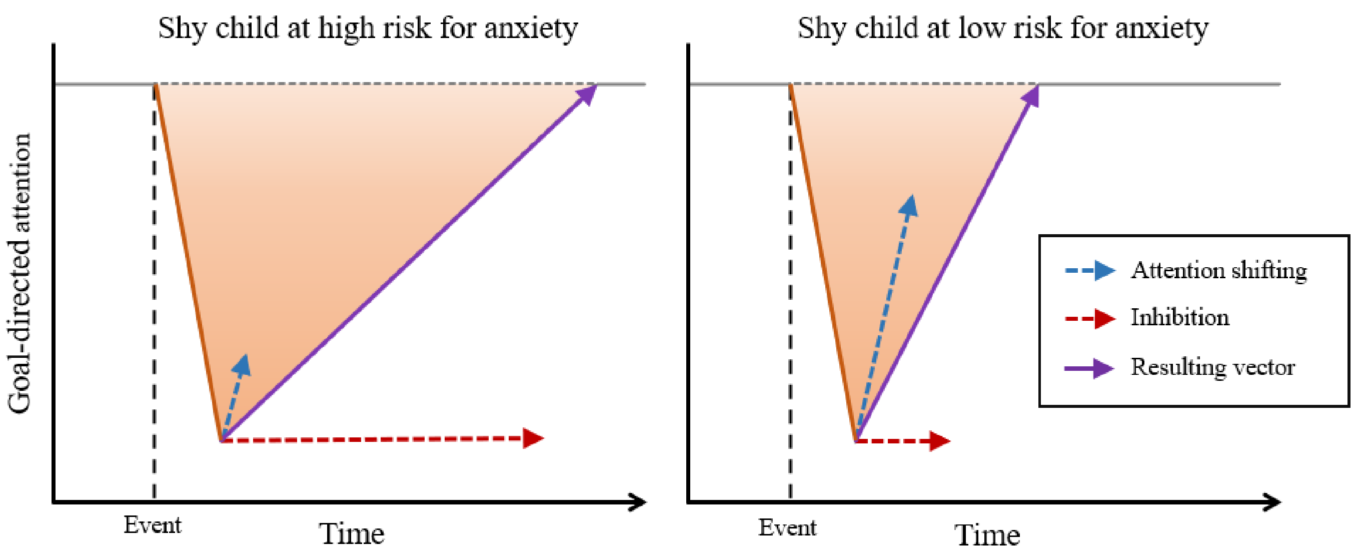

Figure 3. The goal-directed attention of a shy child with greater inhibition relative to attention shifting (left) vs. greater attention shifting relative to inhibition (right) in response to the detection of a salient event in a social context.

By contrast, we propose attention shifting may promote disengaging from the source of the distracting event and shifting attention back toward the task at hand. For example, after noting Colin's sigh, Tyler could shake himself off and bring his attention back to his Legos or their ongoing conversation without skipping a beat (represented by the steeper purple arrow in the right panel of Figure 3). In sum, by enabling children to respond more fluidly and flexibly to the dynamic nature of their interactions with peers, attention shifting may be an important factor underlying healthy social development, particularly for shy and behaviourally inhibited children.

Overview of dissertation

As detailed above, our account (Fox et al., 2021; Henderson & Wilson, 2017) synthesizes a wide body of research on topics related to children's attention, temperament, and self-regulation skills into a unifying framework that proposes elements may interact to predict children's social outcomes. Critically, however, many of the core assumptions of this account have yet to have been empirically tested, and to do so in an ecologically valid manner requires the development of new methods for studying children's social attention *in vivo*. To this end, I conducted three studies with children between the ages of 7 and 11 exploring how various individual and social contextual factors interact to predict children's attention and behaviour, as well as validating new means of examining children's attention and subjective experiences as they occur in social contexts.

Chapter 2 examines how shyness and social context interact to predict children's performance in an attention-demanding task. Chapter 3 investigates turn-taking response time as a novel measure of flexible social engagement during real-world dyadic interactions. Finally, chapter 4 explores the validity of children's reports of their attention to occurrent internal experiences (i.e., mind wandering) while completing a boredom-inducing task.

Shyness, social monitoring, and attentional task performance

Examining core assumptions of our model regarding how child temperament interacts with social context to influence children's attentional behaviour, Chapter 2 explores the idea that even just the perception that one may be evaluated by peers may directly influence how children attend to goal-relevant stimuli and engage with their ongoing goals. Seventy-eight 8-year-old children provided self-reports of their temperamental shyness and completed a hierarchical figures task under two conditions: once under baseline/non-social conditions and once under the impression that their performance was being recorded for later evaluation by peers of the same age.

Results from this study demonstrate how individual differences in children's temperament interact with social contextual factors to predict their goal-directed behaviour. Processes and motivations underlying these differences in performance, as well as implications for children in real-world situations, are discussed.

Turn-taking response time as an *in vivo* index of flexible social engagement

Testing another core assumption of our model (that dynamic and flexible communication is central to the success of children's peer interactions), the study presented in Chapter 3 builds on past theoretical work and adult work to investigate a new means of measuring children's fluid social engagement with peers: the latency of children's communications when engaging in turn-taking conversation. Sixty-two 9- to 11-year-old children divided across 32 dyads were observed interacting with an age- and gender-matched peer for the first time in an unstructured conversational context. Children's verbal behaviours and their response times were coded from recordings of the interaction, as were global ratings of children's openness, social ease, and conversational appropriateness (as coded by an independent team of research assistants).

This study provides insight into how children's ability to quickly and flexibly respond to peers over the course of a turn-taking conversation relates to their own (and their peer's) social behaviour and quality of interaction, offering a promising new direction for future research examining children's flexibility in real-world social interactions.

The validity of children's reports of internal experiences

Another important step in empirically evaluating our model is considering how children's attention to internal experiences during interactions with peers may influence the quality and fluidity of those interactions. This requires the development of valid means of assessing and interrogating children's subjective internal experiences as they occur. To establish empirical methods which can be used in future investigations informing our theoretical account, the study presented in Chapter 4 seeks to validate 7- to 9-year-old children's reports of *mind wandering*, a ubiquitous phenomenon that has been amply studied in adults but scarcely studied in children. The frequency of children's (N = 81) reports of mind wandering was recorded while they completed a simple boredom-inducing task previously unused in past child research: the Metronome Response Task (MRT; Seli et al., 2013). Children's behavioural performance on this task, which correlates with adults' self-reports of mind wandering, was used to corroborate children's reports. This study also examined how parent reports of executive dysfunction in daily life related to children's reports of mind wandering and behavioral performance in the MRT.

Findings from this study shed light on children's experience of internal mental events and their ability to report on such experiences as they occur in a goal-directed context, as well as how aspects of self-regulation influence children's reports. By working to establish the validity of children's introspective self-reports in middle childhood, this study opens the door for the use of experience-sampling to access children's subjective experiences across several domains.

Chapter Two: Shyness and perceived monitoring by peers impact children's performance in a divided attention task.

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Introduction

Faced with new people, situations, and experiences every day, children must come prepared to efficiently process incoming information in order to learn and engage with the dynamic world around them. Notably, from a very young age, children vary in their reactions to new and challenging events, with many of these individual differences predicting later developmental outcomes (e.g., Asendorpf, Denissen, & van Aken, 2008; Chronis-Tuscano et al., 2009; Clauss & Blackford, 2012). This presents the unique challenge of understanding how the various aspects of child temperament impact basic cognitive processes, and how these individual differences are manifest in real world situations. The goal of the current study is to examine how individual differences in shyness relate to children's ability to allocate and shift their attention in a goal-directed experimental setting, and further how these attentional processes are influenced by social factors such as the perception of being monitored by peers.

Attentional processing of the visual environment is frequently studied using hierarchical compound figures, consisting of arrays of small 'local' items arranged to form larger 'global' figures (e.g., an array of small X's forming a larger letter H; Navon, 1977). As hierarchical figures can be perceived both atomistically as collections of individual items, and holistically as single representations, this paradigm illustrates how humans organize and attend to complex visual stimuli under various conditions. Adults consistently exhibit a global bias in the processing of hierarchical stimuli, such that global-level information is processed more quickly and with less interference from task-irrelevant information than local-level information, referred to as global precedence (Krakowski, Borst, Pineau, Houdé, & Poirel, 2015; Navon, 1977; Poirel et al., 2013). While physical characteristics such as visual angle (Kinchla & Wolfe, 1979) and stimulus density (Kimchi & Palmer, 1982; Krakowski et al., 2018) influence performance, low-level perceptual factors cannot fully account for the pre-eminence of global information, and attentional processes are believed to play a major role (Lamb & Robertson, 1990).

Developmental work demonstrates that the presentation of global-local biases varies notably across childhood and adolescence. Generally, the ability to integrate information from differing levels of hierarchical stimuli improves over the course of childhood (Burack et al., 2000; Kovshoff, Iarocci, Shore, & Burack, 2015; Krakowski et al., 2018; Porporino, Shore, Iarocci, & Burack, 2004; Poirel, Mellet, Houdé, & Pineau, 2008). Some studies report children exhibit local biases in early and middle childhood, shifting to a global bias later in adolescence (Scherf, Behrmann, Kimchi, & Luna, 2009), whereas others report global biases in children as early as age 5, with the processing of local information improving continuously with age (Krupskaya & Machinskaya, 2012; Mondloch et al., 2003). These discrepancies may be due to variation in stimulus characteristics such as the density of local items, to which children are more sensitive than adults (Dukette & Stiles, 2001; Kimchi, Hadad, Behrmann, & Palmer, 2005). Another possibility, however, is that individual differences in children’s processing of hierarchical stimuli, superimposed on normative developmental trends, contribute to the variability in findings across studies.

Individual differences in global-local processing have been identified in both adults (e.g., Dale & Arnell, 2010) and children (Krupskaya & Machinskaya, 2012), and relate to factors including motivation, experience, and personal biases (Burack et al., 2016; Oishi et al., 2014).

Anxiety is a variable of particular relevance to the study of temperament and attention. Easterbrook (1959) proposed that when experiencing emotions such as anxiety, the range of cues processed and used to organize behavior is reduced, “narrowing” attention to the central cues of a stimulus and thereby interrupting the processing of more peripheral information. In a modern investigation of this concept, Gasper and Clore (2002) induced positive or negative moods in their participants before presenting them with a matching task involving hierarchical shapes. Participants in the negative mood condition were more likely to match shapes by their local rather than global properties than were participants in the neutral or positive conditions, consistent with Easterbrook’s account.

In addition to state affect, personality traits involving the experience of negative affect are also associated with attentional narrowing, with high levels of trait anxiety relating to local processing biases (Basso et al., 1996; Derryberry & Reed, 1998; Najmi, Kuckertz, & Amir, 2012). Focusing specifically on trait social anxiety, Yoon, Vidaurri, Joorman, and De Raedt (2015) presented participants with a central image of a human face before briefly presenting a target (a small black dot) in a peripheral location surrounding the face. They found that participants higher in social anxiety were less accurate at identifying the locations where distal targets were presented, suggesting the attentional breadth of socially anxious individuals narrows in the presence of salient social cues. To our knowledge, however, no prior work has examined the role of temperamental traits related to anxiety, such as shyness, in children’s global-local processing in hierarchical figure contexts.

Contextual factors that prime self-focused attention and preoccupation with errors may play particularly important roles in the manifestation of global-local biases among anxious individuals. Derryberry and Reed (1998) found that when negative incentives were highlighted (that is, that points could be lost as a result of poor performance), participants high in trait anxiety processed local items faster than those lower in trait anxiety. When positive incentives were highlighted, participants' performance did not vary as a function of trait anxiety. This suggests that global-local processing biases for anxious individuals may be closely tied to the salience of errors and to the perceived ramifications of poor performance. Narrow attentional focus is likewise associated with other self-evaluative processes such as rumination (DeJong, Fox, & Stein, 2019) and perfectionism (Lopez et al., 2009). With respect to children in middle childhood, contextual manipulations relating to social evaluations by peers might be particularly effective ways of underscoring the costs associated with errors. Pérez-Edgar and Fox (2005) found that when 7-year-old children believed their performance in an attention orienting task would determine whether they had to give a speech to other children of the same age, children exhibited an attentional bias towards punishment cues that was not present under baseline conditions.

In combination with contexts evoking social self-consciousness, temperamental traits associated with anxiety and sensitivity to negative evaluation may significantly impact children's processing of hierarchical stimuli. Temperamental shyness is characterized by fearfulness, discomfort, and hypervigilance in response to social novelty and the prospect of social evaluation (Henderson, 2010; Rubin & Coplan, 2007). When faced with unfamiliar situations and people, shy children tend to keep in close proximity to their caregivers or to withdraw to the periphery of their social environment (Henderson et al., 2004). However, rather than seeking to disengage altogether, shy children continue to observe their peers intently from a safe distance, conceived as evidence of a conflict between approach and avoidance motivations (Coplan et al., 1994).

Another hallmark of shyness is sensitivity to negative peer interactions, such as exclusion or negative evaluations (Rubin & Coplan, 2004; Walker et al., 2014). Recently, Buzzell and colleagues (2017) presented adolescents with an Eriksen Flanker task under two conditions: once under normal testing conditions, and once while under the impression that their performance was being evaluated by a peer. Adolescents identified as behaviorally inhibited (BI; a developmental precursor to shyness) at ages 2 and 3 exhibited greater neural and behavioral indices of error preoccupation (i.e., post-error response slowing) in the peer monitoring condition than those who were not previously identified as behaviorally inhibited. Moreover, these indices of error preoccupation were found to mediate the relationship between BI in early childhood and social anxiety in early adolescence. Using a similar methodology, Barker and colleagues (2018) found that the effect of social monitoring on neural correlates of error preoccupation was only present for children under the age of 12, suggesting that the transition period from middle to later childhood may be a window of heightened sensitivity to the effects of social evaluation on cognitive task performance.

Both Buzzell and colleagues (2017) and Barker and colleagues (2018) found participants' response times were faster under social conditions, suggesting the watchful presence of a peer directly influenced children's performance. However, to our knowledge, no prior work has examined the impact of social monitoring on global-local processing (with children or with adults), nor how this relation may vary as a function of shyness. Humans process the world hierarchically, and global-local processing is an implicit part of many (if not virtually all) attention-demanding activities. This is certainly true of laboratory tasks such as the Eriksen Flanker task, in which attention must be narrowed to the local level while disregarding intrusive global information. However, global-local processing is also an omnipresent aspect of everyday social functioning. In order to engage in high-quality, reciprocal interactions with peers, a child must be able to integrate both subtle local cues (facial expressions, referential gestures) with broader global information (e.g., group dynamics, contextual factors) on a moment-to moment basis. In this way, biases in global-local processing associated with temperamental variables such as shyness or contextual factors such as the perception of being monitored could have long-lasting downstream effects on social functioning. Alternatively, the influence of social monitoring on children's attentional processing may supersede any global-processing biases, altering their overall performance. As such, the current study takes the first steps in informing our understanding of the emergent relations between shyness, attention, and social functioning in middle childhood.

Middle childhood was identified as the developmental period of interest for this study due to its importance in the lifespan development of shyness. While risk factors in the development of shyness (such as BI) have been identified in infancy and early childhood (e.g., Buzzell et al., 2017; Rubin, Coplan, & Bowker, 2009), it is in middle childhood as children's socio-cognitive skills become more sophisticated that self-consciousness emerges and the differential trajectories of shyness become apparent (Buss 1986; Crozier, 1995; Tang et al. 2017). As such, it is pertinent to identify whether attentional factors relating temperament and sensitivity to social monitoring are present in the midst of this developmental period.

The current study addresses this open question by contrasting children's performance on a hierarchical figures task in two conditions: once under typical testing conditions, and once under the impression that their performance is being recorded and will be witnessed by other children of the same age in the near future. Further, while Buzzell et al. (2017) examined the role of BI on children's task performance under social conditions, it remains to be seen how children at the other end of the shyness spectrum (i.e., more outgoing, exuberant children) are influenced by the perception of peer monitoring. ‘Social facilitation’ is a phenomenon wherein performance on simple or highly practiced tasks is improved in the presence of others (Allport, 1924; Bond & Titus, 1983; Zajonc, 1965). Importantly, in both children and adults, social facilitation is most pronounced in individuals high in extraversion, self-esteem, and the willingness to be subject to appraisal (Levin, Baldwin, Gallwey, & Paivio, 1980; Uziel, 2007). As such, for exuberant children, rather than having an inhibitory or anxiety-inducing effect, the perceived presence of peers may facilitate performance, capitalizing on their reward sensitivity by offering them the opportunity to impress peers (Dollar, Stifter, & Buss, 2017). The current study incorporated a continuous measure of shyness to explore this possibility.

The bulk of past studies in the area have used selective attention designs, wherein the speed and accuracy with which children can identify targets at a given level (global or local) is measured while task interference is manipulated by presenting targets at the other goal-irrelevant level. Relatively fewer studies have explored children’s processing of hierarchical figures using divided attention designs, wherein targets may appear at either global or local levels and participants are not instructed to which level to attend. Using this design, the speed and efficiency with which children shift their attention between levels in response to task demands can be examined. As the level to which one should attend is not specified, participants need to self-initiate shifts in their attention, more closely approximating the dynamic nature of attention shifting in social contexts. Past work has identified a level-repetition effect, whereby responses are completed more quickly when the target on a given trial appears at the same level as the target in the previous trial (e.g., Hubner, 2000; Lamb et al., 1998).

To pull together these disparate literatures, the goals of the current study were to (1) extend prior work by examining children's ability to shift their attention between the levels of hierarchical figures using an inferential task design, (2) evaluate the impact of social monitoring on children's attention deployment, and (3) explore whether this sensitivity to social context varies as a function of individual differences in shyness. In line with past hierarchical figure studies (e.g., Lamb et al., 1998; Mondloch et al., 2003), it was hypothesized that children would be faster and more accurate when processing global than local information, as well as when information was presented at the same level on the previous trial (Hypothesis 1). With respect to social monitoring, based on the behavioral results from Buzzell and colleagues (2017) and Barker and colleagues (2018), it was hypothesized that, at the group level, children would respond faster under social relative to non-social conditions (Hypothesis 2). However, when accounting for individual differences, it was hypothesized that shyer children would respond more slowly and more accurately than less shy children under social monitoring conditions (Hypothesis 3), consistent with Buzzell and colleagues' (2017) findings regarding behavioral inhibition and error preoccupation.

Methods

Participants

Eighty-one typically-developing children living in Southern Ontario participated as part of a short-term longitudinal study of temperament, cognition, and social-emotional functioning in middle childhood. Participants were recruited through community events, social media (e.g., Facebook, Kijiji) and by letters distributed to local schools. At the time of their visit, participants were between 8.0 and 9.1 years old. Two participants were excluded for failing to follow instructions during the administration of questionnaires, and one participant was excluded for choosing not to complete the task, resulting in a final sample of 78 (Mage = 8.34, SD = .31, 55.1% female). Ethnic demographics were generally representative of that in the surrounding community (91.0% Caucasian, 2.6% South Asian/West Asian/Arab, and 6.4% mixed race/other) and parent education levels were varied (maternal/paternal education: 0%/2.6% less than high school, 5.1%/9% high school, 6.4%/9.0% some university/college, 15.4%/16.7% 2-year college, 34.6%/29.5% 4-year university, 38.5%/28.2% advanced/professional degree.)

Measures

Participants completed a battery of computerized tasks and questionnaires as part of the broader study. Measures of interest for the current study are described below.

Child Shyness Questionnaire (CSQ). The CSQ (Crozier, 1995) is a 26-item self-report questionnaire assessing the behavioral, affective, and physiological manifestations of children's shyness. For each item, children respond with "No", "Sometimes", or "Yes" (scored as 0, 1, and 2, respectively). Twenty-one items probed the experience of shyness directly, including "I find it hard to talk to someone I don't know", "I go red when someone teases me", and "I feel shy when I am the centre of attention". Five reverse-scored items assessed children's inclination toward more exuberant behavior, including "I enjoy singing aloud when others can hear me", and "I say a lot when I meet someone for the first time." Responses were summed to yield a continuous Shyness score ranging from 0 to 52, with higher scores indicating higher levels of shyness. CSQ scores correlate with relevant outcomes such as perceived social acceptance and self-worth (Crozier, 1995). In the current sample, the internal consistency of the CSQ's items was high, α = .84.

Divided Attention Task (DAT). The DAT was designed and presented using E-Prime 3.0 (Psychology Software Tools, Pittsburgh, PA) on a 50.8x28.6 cm screen HP monitor displayed at 1920x1080 resolution. Experimental stimuli consisted of an array of small 'local' letters presented in a bold monospaced font (Consolas) arranged to form a large 'global' letter, drawn in black on a white background (see Fig. 4). Dimensions of the global figure were 3.5 cm long by 2.7 cm wide, subtending of 4° and 3° of visual angle, respectively. Local letters were

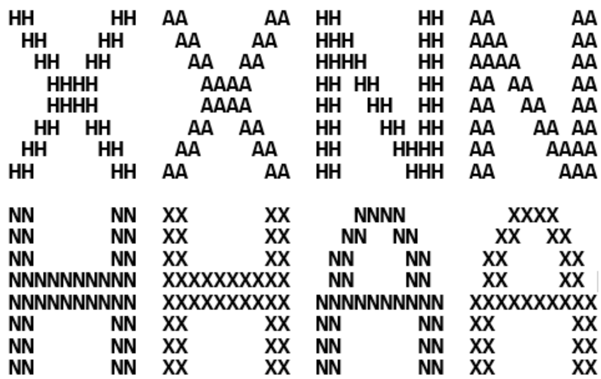

Figure 4. Stimuli from the Divided Attention Task. The top row contains stimuli from Global trials, wherein targets (X or N) are present at the global level, while the bottom row contains stimuli from Local trials, wherein targets are present at the local level.

0.3 cm long by 0.2 cm wide, subtending .34° and .23° of visual angle, respectively. One of two target letters, X or N, would be present. In global trials, targets appeared at the global level, while in local trials, the target appeared at the local level. Distractor letters, A or H, populated the non-target level of each trial, resulting in eight possible combinations of targets and distractors. The level at which the target appeared varied unpredictably from one trial to the next. In stay trials, the target was presented at the same level as in the preceding trial (e.g., a global trial following a global trial), whereas in shift trials, the target level changed across trials (e.g., a local trial following a global trial).

Procedure

Parent consent and child assent were collected at the beginning of the visit to the lab, after which participants completed a battery of tasks and questionnaires in a randomized order.

CSQ. Participants were seated at a table in a quiet room across from an experimenter, each with a paper copy of the CSQ. The experimenter read each item aloud, and participants circled their response to each item on their copy of the questionnaire.

DAT. Participants were seated 50 cm from the screen. A ribbon affixed to the left side of the monitor was used to ensure each participant was seated at the appropriate height and distance from the screen, and participants were instructed to remain still for the duration of the task. If the participant moved considerably out of position (e.g., leaning forward), the experimenter would instruct the participant to pause and the participant would be reoriented using the ribbon.

Before beginning the task, participants were introduced to the hierarchical figures used in the task. Participants were informed that their goal was to identify which of two target letters, X or N, was present in each stimulus. After completing 10 practice trials with feedback on response accuracy, participants completed 81 experimental trials. As the first trial is by definition neither a stay or shift trial, performance on the first trial was excluded from all analyses, resulting in 80 test trials.[1] Trial orders were pseudorandomized such that no more than three trials of any type (global/local, stay/shift) were presented in sequence.

Each participant completed the DAT two times under different conditions (the order of which was counterbalanced across participants). In the Baseline condition, participants completed the DAT with no contextual manipulations. In the Social Monitoring condition, after the completion of practice trials and prior to beginning the task, the experimenter introduced a video camera. Participants were deceived into believing that their performance of the task would be recorded and presented to other children their age who would be able to evaluate the participant's performance. Parents provided prior consent to this use of deception. Immediately after completing the Social Monitoring condition of the DAT, participants were debriefed on the nature of the deception in the presence of their parent. Participants were given the opportunity to

[1] 1 Due to a programming error, a subset of participants completed 21 global–stay trials and 19 local–stay trials (as opposed to 20 of each) in one block of their two blocks of the task (21 participants in the Baseline condition and 18 participants in the Social Monitoring condition). Their performance did not differ systematically from the rest of the sample in any respect.

ask questions and withdraw their consent for data to be collected from the task; ultimately, none opted to do so.

Analyses

First, to evaluate participants' performance on the DAT, two mixed factorial ANOVAs were run with mean accuracy and RTs as dependent variables, respectively. Each ANOVA included Condition (Baseline vs. Social Monitoring), Level (Global vs. Local), and Trial Transition (Shift vs. Stay) as within-subject factors, and Condition Order (Baseline-Monitoring vs. Monitoring-Baseline) as a between-subjects factor. Only correct trials were included in RT analyses, and trials in which participants' RTs were more than 3 standard deviations above their mean RT for that block were excluded from analyses. This exclusion criterion resulted in the loss of an average of 1.44 trials per block of 80 trials.

Next, in line with Buzzell et al.'s (2017) analyses comparing performance between social and non-social conditions, a series of hierarchical regressions were run to assess whether temperamental shyness relates to variation in DAT performance as a function of social monitoring. Separate sets of analyses were run for accuracy and RT. For each DV, an initial regression collapsing across all stimulus conditions of the DAT was run to assess the general impact the social monitoring manipulation on task performance. Next, to explore whether the effect of the social manipulation varied as a function of the hierarchical level being processed and/or shifting demands, a series of regressions were run evaluating performance on each trial type (Global-Shift, Global-Stay, Local-Shift, Local-Stay).

In the first step of each regression, in line with analyses from Buzzell and colleagues (2017), scores from the social monitoring condition were regressed onto scores from the baseline condition. In the second model, condition order was added as a predictor (Baseline-Monitoring coded as 0, Monitoring-Baseline coded as 1), accounting for differences in social monitoring performance attributable to the order in which the conditions were performed (that is, whether the social monitoring block was performed first or second). As such, the residuals yielded by this second model represent the differences in task performance solely attributable to the effect of perceived monitoring by a peer. Having isolated the social monitoring effect, CSQ Shyness was added as a predictor in the final model to assess the impact of temperamental shyness on performance under social conditions.

De-identified data, supplementary analyses, and other related documentation are accessible through the Open Science Framework (OSF) project associated with this study (https://osf.io/ensh7/?view_only=64f5cffff36846ed8825b58de912d4b0).

Results

Overall Descriptive Statistics

Means and standard deviations for accuracy and RT across all conditions of the DAT are presented in Table 1. CSQ scores were normally distributed in the sample, ranging from 5 to 44, $M = 22.08$, $SD = 8.99$.

Mixed Factorial ANOVAs

Accuracy. There was no significant main effect of condition, $F(1, 76) = 0.521$, $p = .472$, indicating that overall, participants were equally accurate in the Baseline and Social Monitoring conditions. Consistent with Hypothesis 1, there was a significant main effects of level, $F(1, 76) = 7.05$, $p = .010$, $\eta p2 = .09$, such that participants identified Global targets more accurately than Local targets. Also consistent with Hypothesis 1, there was a significant main effect of trial transition, $F(1, 76) = 16.79$, $p < .001$, $\eta p2 = .18$, such that participants were more accurate when targets stayed at the same level as in the previous trial than when targets shifted levels across

Table 1.

Descriptive statistics for the DAT, reported as 'Mean (*SD*)'. Accuracy is reported as percent (%) correct, and response time is reported in milliseconds (ms).

Condition	Baseline-Monitoring		Monitoring-Baseline		Overall	
	Accuracy	RT	Accuracy	RT	Accuracy	RT
Baseline						
Global						
Shift	97.56 (*4.42*)	1461 (*347*)	95.00 (*5.96*)	1258 (*406*)	96.28 (*5.37*)	1360 (*389*)
Stay	97.99 (*2.70*)	1383 (*421*)	96.97 (*4.20*)	1221 (*360*)	97.48 (*3.54*)	1302 (*397*)
Local						
Shift	95.26 (*6.58*)	1505 (*376*)	93.85 (*7.82)*	1321 (*422*)	94.55 (*7.22*)	1413 (*407*)
Stay	96.78 (*4.94*)	1348 (*328*)	95.22 (*6.50*)	1196 (*343*)	96.00 (*5.79*)	1272 (*342*)
Monitoring						
Global						
Shift	96.54 (*5.87*)	1140 (*231*)	96.03 (*5.52*)	1472 (*371*)	96.28 (*5.67*)	1306 (*349*)
Stay	97.59 (*4.38*)	1152 (*208*)	96.84 (*3.66*)	1313 (*319*)	97.22 (*4.03*)	1232 (*280*)
Local						
Shift	96.15 (*4.65*)	1230 (*251*)	94.36 (*6.41*)	1455 (*364*)	95.26 (*5.64*)	1343 (*331*)
Stay	97.66 (*4.19*)	1163 (*249*)	96.50 (*5.78*)	1300 (*343*)	97.08 (*5.04*)	1231 (*306*)

subsequent trials. Trial accuracy plotted as a function of Level and Trial Transition is presented in Figure 5a.

There was a main effect of Condition Order, $F(76) = 4.34$, $p = .041$, $\eta p2 = .05$, such that participants in the Baseline-Monitoring group were slightly more accurate overall than those in the Monitoring-Baseline group. There were no other significant main effects or interactions.

Response Time (RT). Consistent with Hypothesis 2, the effect of condition was significant, $F(1, 76) = 4.53$, $p = .037$, $\eta p2 = .056$, such that overall, participants responded faster in the Social Monitoring than in the Baseline condition. This effect was further qualified by an interaction between condition and condition order, $F(1, 76) = 49.99$, $p < .001$, $\eta p2 = .397$. Post-hoc analyses revealed that participants responded faster in their second block of trials regardless of its condition, with participants in the Baseline-Monitoring group responding faster in the Social Monitoring block than in the Baseline block, $t(38) = 7.37$, $p < .001$, $d = 1.18$, and participants in the Monitoring-Baseline group responding faster in the Baseline block than in the Social Monitoring block, $t(38) = -3.16$, $p = .003$, $d = 0.51$. Accordingly, RTs in the Baseline block were faster for the Monitoring-Baseline group than for the Baseline-Monitoring group, $t(76) = 2.19$, $p = .031$, $d = 0.50$, while RTs in the Social-Monitoring block were faster for the Baseline-Monitoring group than the Monitoring-Baseline group, $t(65.51) = -3.36$, $p = .001$, $d = 0.76$. For the latter analysis, degrees of freedom were adjusted as Levene's test indicated unequal variances, $F = 4.01$, $p = .049$. Regardless of what condition (Baseline or Monitoring) participants completed first, overall there were no significant differences between the groups' RTs in their first block of trials, $t(76) = .525$, $p = .601$, or second block of trials, $t(76) = -1.13$, $p = .264$.

Consistent with Hypothesis 1, there was a significant main effect of Trial Transition, $F(1, 76) = 77.79$, $p < .001$, $\eta p2 = .51$, such that overall, participants were faster in Stay than Shift

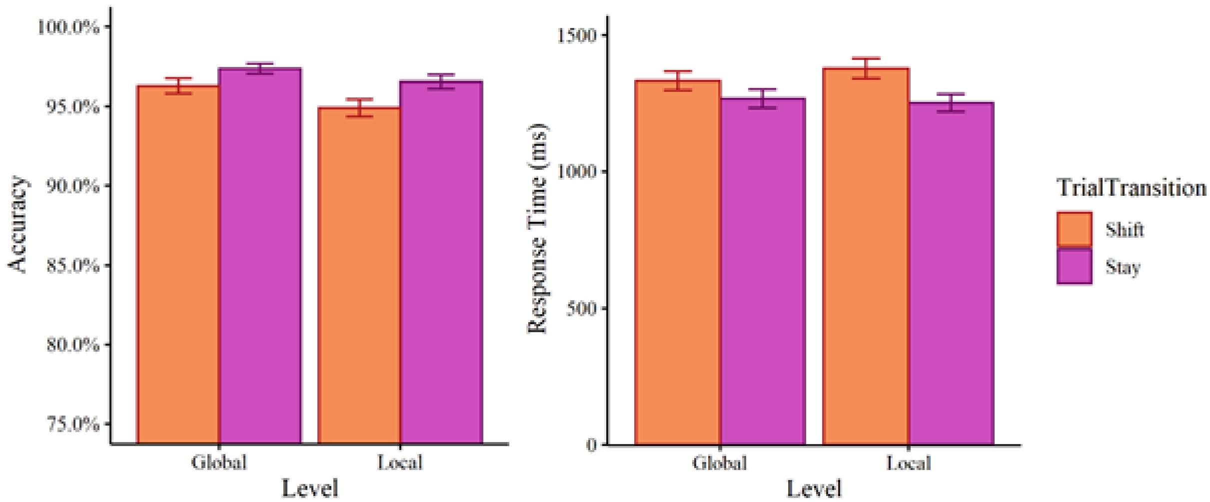

Figure 5. Mean accuracy (a, left) and RT (b, right) as a function of Level and Trial Transition. Error bars represent SE (+/-1).

trials. There was no significant main effect of level, F(1, 76) = 1.40, p = .240, however there was a significant Level-by-Trial Transition interaction, F(1, 76) = 7.54, p = .008, ηp2 = .09. Post hoc analyses revealed that participants were faster when shifting to the Global level than when shifting to the Local level, t(77) = -2.66, p = .010, d = 0.30, while there was no difference in RT when staying at the Global or Local level, t(77) = 0.965, p = .337. Participants responded more quickly in Stay than in Shift trials for both Global, t(77) = -4.00, p < .001, d = 0.45, and Local trials, t(77) = 8.47, p < .001, d = 0.96. Mean RTs plotted as a function of Level and Trial Transition are presented in Figure 5b.

There were significant three-way interactions between Condition, Condition Order, and Level, F(1, 76) = 4.42, p = .039, ηp2 = .055, as well as between Condition, Condition Order, and Trial Transition, F(1, 76) = 13.63, p < .001, ηp2 = .152. As these interactions were neither hypothesized nor of direct theoretical relevance to the study, post-hoc analyses parsing these interactions are not presented here, but are available through the OSF (see ‘Analyses’).

Regressions with Shyness

Response time (RT). An omnibus regression assessed the general impact of the social monitoring manipulation on participants' response time, collapsing across all trial types. Regression statistics for the final model are presented in Table 2, while those for the preceding steps are available through the OSF (see 'Analyses). In the first step, Baseline RT significantly improved the model, $F(1, 76) = 36.83$, $p < .001$, accounting for 32.6% of the variation in RT. In the second step, the addition of Condition Order significantly improved the model, $F(1, 75) = 48.73$, $p < .001$, accounting for an additional 26.5% of the variation. Having isolated the variance in performance attributable to the social monitoring manipulation, CSQ Shyness was then added as a predictor in the third model. Consistent with Hypothesis 3, results indicate that CSQ Shyness significantly improved the model, $F(1, 74) = 14.87$, $p < .001$, accounting for an additional 6.8% of the variation. That is, as shyness increased, participants responded more slowly in the Social Monitoring condition relative to the Baseline condition, regardless of condition order. The final step of this model is presented visually in Figure 6.

Regressions following the same steps were run to explore the effects of the social monitoring manipulation on RT for each trial type (Global-Shift, Global-Stay, Local-Shift, Local-Stay). Results were highly consistent with those of the omnibus regression; each successive step contributed significantly to the model, and in the final model of each regression, each predictor was significant. As such, these exploratory results do not suggest the relation between shyness and the social monitoring effect varies as a function of hierarchical level or shifting between levels. Regressions statistics for each analysis are available through the OSF (see 'Analyses).

To ensure the relation between shyness and the social monitoring effect was similar regardless of the order in which participants completed the two conditions, the omnibus

Table 2.

Hierarchical multiple regressions predicting Social Monitoring scores (final models)

Mean RT[a]		*B*	*SE B*	*β*	*t*	*p*
	Intercept	37.914	118.420	-	0.370	.750
	Baseline RT	0.642	0.060	.779	10.707	<.001
	Condition Order	357.895	42.889	.604	8.345	<.001
	CSQ Shyness	9.205	2.387	.278	3.856	<.001
Accuracy[b]						
	Intercept	0.782	0.105	-	7.473	<.001
	Baseline Accuracy	0.191	0.107	.205	1.777	.080
	Condition Order	-0.007	0.008	-.097	-0.831	.409
	CSQ Shyness	0.000	0.000	.037	0.321	.749

[a] *Note*. $N = 78$. Multiple $R = .812$; $R^2 = .660$; adjusted $R^2 = .646$; $SE = 177.21$.
[b] *Note*. $N = 78$. Multiple $R = .252$; $R^2 = .063$; adjusted $R^2 = .025$; $SE = 0.04$.

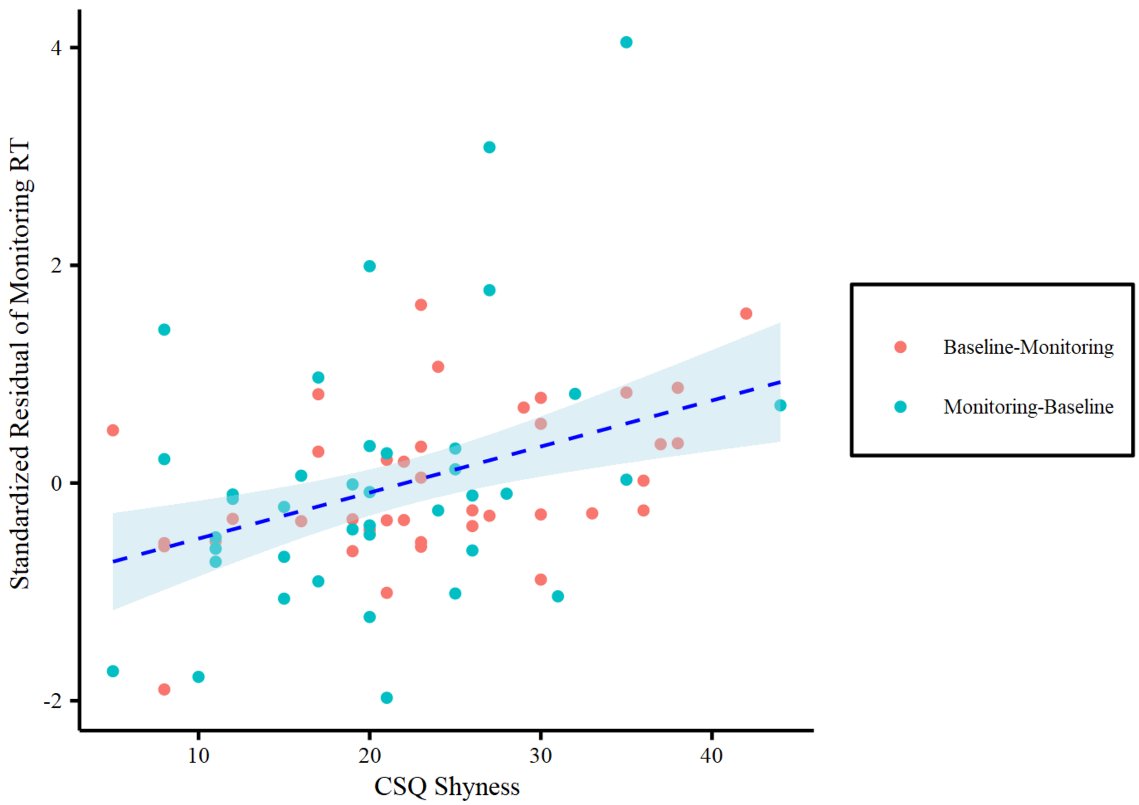

Figure 6. CSQ Shyness plotted against the standardized residual of Monitoring RT, controlling for Baseline RT and Condition Order. Positive y-values indicate an increase in RT (slowing) attributable to the social monitoring effect, while negative values indicate decrease in RT. Shaded area indicates 95% confidence interval.

regression was re-run analyzing each Condition Order group separately ($n = 39$, respectively). In these post-hoc analyses, Social Monitoring RT was first regressed onto Baseline RT, thereby isolating the effect of the social monitoring manipulation, before adding CSQ Shyness as a predictor. For the Baseline-Monitoring group, Baseline RT contributed significantly to the model, $F(1, 37) = 58.52$, $p < .001$, accounting for 61.3% of the variation in RT. Consistent with Hypothesis 3, the addition of CSQ Shyness significantly improved the model, $F(1, 36) = 7.33$, $p = .010$, accounting for an additional 6.6% of the variation. For the Monitoring-Baseline group, Baseline RT contributed significantly to the model, $F(1, 37) = 37.86$, $p < .001$, accounting for 50.6% of the variation in RT. Consistent with Hypothesis 3, the addition of CSQ Shyness significantly improved the model, $F(1, 36) = 7.65$, $p = .009$, accounting for an additional 8.7% of the variation. In sum, results from these post-hoc analyses confirm that the effect of shyness was comparable for participants completing the conditions in either order. Refer to Figure 6 for a visual comparison of the two groups, distinguished by color.

Accuracy. An omnibus regression assessed the general impact of the social monitoring manipulation on participants' accuracy. Regression statistics for the final model are presented in Table 2, while those for the preceding model are available through the OSF (see 'Analyses). In the first step, Baseline Accuracy contributed significantly to the model, $F(1, 76) = 4.14$, $p = .045$, accounting for 5.2% of the variation in Social Monitoring Accuracy. In contrast to RT, the addition of Condition Order did not significantly improve the model, $F(1, 75) = 0.83$, $p = .364$. nor did the addition of CSQ Shyness in the final model, $F(1, 74) = 0.10$, $p = .749$. That is, contrary to Hypothesis 3, while shyness was related to a slowing in children's responding as a function or the social monitoring manipulation, shyness was not similarly related to changes in accuracy across conditions.

Regressions following the same steps were run to evaluate the effects of the social monitoring manipulation on accuracy for each trial type (Global-Shift, Global-Stay, Local-Shift, Local-Stay). In each of these follow-up analyses, in contrast to the omnibus analysis, Baseline Accuracy did not contribute significantly to the model in the first step (ps < .05). Subsequent steps were similarly non-significant, consistent with the omnibus analysis. Regressions statistics for these analyses are available through the OSF (see 'Analyses').

Discussion

The goals of the current study were to (1) extend prior work by examining children's ability to shift their attention between the levels of hierarchical figures using an inferential task design, (2) evaluate the impact of social monitoring on children's attention deployment, and (3) explore whether this sensitivity to social context varies as a function of individual differences in shyness. Overall, children exhibited a global bias in the processing of hierarchical stimuli. Moreover, the Social Monitoring condition impacted children's performance as a function of shyness; children self-reported as low in shyness responded faster in response to the social monitoring manipulation, whereas for children high in shyness, the opposite was true.

Supporting Hypothesis 1 and in line with several past studies (e.g., Burack et al., 2000; Derryberry & Reed, 1998; Krakowski et al., 2018), the current study found evidence of a global bias in children's processing of hierarchical stimuli. Participants identified targets more accurately when they appeared at the global level, and were faster when shifting to the global than to the local level. Building on past work with adults (Lamb et al., 1998; Katagiri et al., 2013), there was a clear effect of level-repetition, such that participants were faster to respond when targets remained at the same level across trials. Consistent with each of these effects, participants were most accurate on Global-Stay trials, where both the target level and carryover effects from the previous trial facilitated performance.

As the sizes of the global and local items were held constant across all trials, it is possible that the dominance of global information may have been influenced by the particular visual angles at which stimuli were perceived by participants. Further the use of a ribbon to measure children's distance from the screen, rather than a more restrictive apparatus such as a chin rest, may also have introduced some variability in the data. Importantly however, while low-level sensory processes such as visual acuity can influence hierarchical processing at certain bounds (Kinchla & Wolfe, 1979), higher-level attentional processes primed by the features of a set of trials also play a major role in the manifestation of attention biases (see Lamb & Robertson, 1990). The visual angles selected in the current study are representative of normative, mid-range values from the range of stimulus sizes used in past studies (e.g., Katagiri et al., 2013; Plaisted et al., 1999; Song & Hakoda, 2015). As such, findings from the current study support accounts of global dominance in middle childhood, with recognition that more work is necessary to fully understand the interplay of high- and low-level processes underlying children's hierarchical processing.

Overall, supporting Hypothesis 2, children responded faster in the Social Monitoring condition than in the Baseline condition. This is consistent with the findings from Buzzell and colleagues (2017) and Barker and colleagues (2018), who found children responded faster in social conditions using similar social monitoring manipulations. However, there was a notable effect of condition order on children's response times, such that children were significantly faster in their second block of trials. Buzzell and colleagues and Barker and colleagues used similar manipulations and counterbalancing procedures but do not present data on potential order effects. In addition to using different measures, the children assessed in these studies were older (with mean ages of 13.18 and 11.87 years, respectively) than in the current sample (with a mean age of 8.34). It is possible that younger children may require longer to habituate to the demands of the task, leading them to respond more quickly in the second block of trials, while older children may not require this same amount of time to 'warm-up'. Pérez-Edgar and Fox (2005), studying children closer in age to those in the current study (7-year olds), also found differences in response time across children's first and second blocks of trials. However, as the order of the baseline and affective conditions in this study was not counterbalanced across conditions, it is not fully clear to what extent these differences in response time are attributable to order effects as opposed to experimental manipulations. As counterbalancing is an integral part of evaluating within-subjects effects, the inclusion of lengthy practice blocks may be the best means of mitigating condition order effects in future studies with children in this age range.

Despite this condition order effect, the social monitoring manipulation was nonetheless found to relate to children's performance as a function of shyness, such that as children's self-reported shyness increased, the residual variance in Social Monitoring RT positively increased. As presented in Figure 6, at the low end of the shyness spectrum, predicted values were negative, indicating a decrease in RT, while at the high end of the spectrum, predicted values were positive, indicating an increase in RT. This relation suggests that the social monitoring manipulation had a slowing effect on shyer children, but a hastening effect on more exuberant children. Notably, these changes in response behavior emerging as a function of shyness were not reflected in an association between shyness and accuracy across conditions. Indeed, across the sample and in both the Social Monitoring and Baseline conditions, accuracy was consistently high with mean accuracy rates above 94% (see Table 1). As such, the question becomes "what underlying processes or motivations resulted in these differences in performance arising as a function of shyness?"

One account of the slowing of shyer children, consistent with past work by Buzzell and colleagues (2017) and Barker and colleagues (2018), is that the perception of being monitored by peers led to increased wariness and the adoption of a strategy involving excessive self-monitoring. The demands of the DAT are quite basic (spot the X or N in each figure), as demonstrated by the high accuracy rates recorded in the sample. Stimuli never contained conflicting information (e.g., distractors whose influence may need to be inhibited, as in selective attention tasks), and thus errors are almost entirely contingent on impulsive responding with a disregard for the stimuli. As such, if children's internally defined goals were to maximize both speed and accuracy while completing the task, shy children's slowing in response to the social monitoring manipulation would be demonstrably inefficient.

Alternatively, for shy children, optimizing speed and accuracy may not have been the goal; for these children, the internally defined goal may have been "Do not make mistakes at any cost." Rather than capitalizing on the task's low difficulty, the fear that another child might witness an error may have encouraged shyer children to slow down and respond trepidatiously despite its relative simplicity. One avenue for future research is to consider whether in social contexts, shy and non-shy children differ in their ability to alter their performance strategies in response to varying task demands. Whereas low-shy children may be able to flexibly alter their performance in response to changing task demands (e.g., increasing self-monitoring as the need for inhibition increases) or externally defined goal states (e.g., shifting from maintaining high accuracy to maintaining fast RT), high-shy children may struggle to do so in the presence of peers, defaulting to a high self-monitoring regardless of task demands. Further, in addition to relying on traditional performance metrics (RT, accuracy rates), future work may consider incorporating drift diffusion models as a means of uncovering the motivational decision processes underlying children's performance under social conditions (see Ratcliff & McKoon, 2008; White, Servant, & Logan, 2018).

Conversely, for children low in shyness, the perception that they were performing in front of others may have had a motivating effect, prompting them to complete the task quickly without negatively impacting accuracy. Given the relative simplicity of the DAT, children lower in shyness may have been motivated to demonstrate their mastery of the task by hastening their responses without sacrificing accuracy, while shyer children were unable to capitalize on this opportunity. By contrast, in the absence of the extrinsic motivation to impress an audience in the baseline condition, children lower in shyness may have been less engaged in the task than children higher in shyness. It is worth noting that the CSQ was designed to probe children's experience of shyness (or their lack thereof), and while some of the CSQ's reverse scored items do probe children's experience of exuberance, the measure itself does not expressly assess children's exuberance or approach motivation with regards to social interactions. Future studies should consider including measures that assess children's self-reported exuberance explicitly in order to more directly examine its relation with performance under social (as opposed to non-social) conditions.

As an alternative account, rather than having a top-down effect on children's motivational strategies, the social monitoring manipulation may have had a bottom-up effect on children's attentional processes. That is, the emotions or cognitions evoked by the social monitoring manipulation may have directly impacted children's attentional and executive processes, influencing their ability to search the array, identify targets, and/or engage responses. Wolfe and Bell (2014) noted that among children scoring low in measures of executive functioning (EF), shy children exhibited an increase in frontal EEG power from baseline-to-task while non-shy children did not, despite similar behavioral performance. The authors propose this increase in brain activity unrelated to task performance may be due to self-conscious, task-irrelevant thoughts occurring during the completion of the task, referred to as 'cognitive busyness'. The social monitoring manipulation in the current study may have evoked a similar effect; primed to experience the intrusion of self-evaluative thoughts during the task, shy children may have become more distracted during the social monitoring block, thereby requiring more time and effort to respond. The combined use of physiological indices of effortful control such as heart rate variability (e.g., Holzman & Bridgett, 2017) and randomly-occurring thought-probes directly assessing children's thought content (e.g., Keulers & Jonkman, 2019) may be a promising means of evaluating the role of cognitive busyness in children's cognitive task performance under social conditions.

Other work suggests that positive affect facilitates cognitive flexibility, which may have likewise facilitated children's ability to navigate the hierarchical stimuli presented in the DAT (Grol & De Raedt, 2018; Yang & Yang, 2014). However, while state anxiety is detrimental to performance in cognitive tasks involving emotionally valenced or affectively salient information (i.e., tasks that assess 'hot' cognition; Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010; Robinson, Letkiewicz, Overstreet, Ernst, & Grillon, 2011), anxiety enhances performance in 'cold' tasks such as the Go-No Go task (Robinson, Krimsky, & Grillon, 2013). From this perspective, given that the DAT is likewise a 'cold' task, one might expect increases in anxiety elicited by the social monitoring manipulation to improve shy children's performance. Individual differences in children's motivations, wherein shy children seek to avoid making errors in the presence of peers, would account for the current study's findings. Future studies should consider prompting children to report on their motivational states and conscious response strategies before/while completing social vs. non-social tasks to fully clarify the relations between shyness, social monitoring, and performance. Further, the DAT completed by participants in the current study was relatively undemanding, as evinced by participants' high accuracy rates. As such, it remains unknown how high- and low-shy would have differed in performance under more demanding conditions (e.g., a limited response window, interference from an interference task completed in tandem). Future research building on the current study should manipulate factors such as task difficulty to examine how the strategies and performance of shy vs. non-shy children differ in a broader range of circumstances.

Regressions examining the relation between shyness and performance under specific trial conditions (Global-Shift, Global-Stay, Local-Shift, Local-Stay) yielded highly similar results to the omnibus analysis, suggesting that the effects of the social monitoring manipulation did not vary as a function of hierarchical level or trial transition. Notably, the current study did not directly test for interactions between shyness, condition, level, and trial transition in a unified analysis. Examining the effect of the social monitoring manipulation was the foremost goal of the study. Given the modest observed effect size of shyness as a predictor as well as the notable effect of condition order, exploring further interactions would exceed the power limitations of the current study. As such, conclusions drawn from these parallel analyses should be interpreted as exploratory.

To our knowledge, the current study is the first to examine how individual differences in temperament and social contextual factors influence children's performance on a hierarchical figures task. The perception of being monitored by peers has a marked impact on children's task performance as a function of shyness, causing low-shy children to speed up and high-shy children to slow down, without any penalties or gains in accuracy, respectively. Considering a wide range of factors in a controlled context, the current study attempts to shed light on the processes underlying children's cognition in the real-world, where the presence of others may influence their ability to act and interact with others. Only by accounting for both individual factors such as temperament and contextual factors such as the watchful presence of others can the complex interrelation between cognition and early temperament be understood.

Chapter Three: Shyness, Engagement, and Conversational Response Times in Children's Dyadic Interactions with an Unfamiliar Peer

Introduction

Learning how to effectively engage with peers and build lasting relationships is a central part of children's social development, with implications for well-being across the lifespan. Support from peer relationships is associated with a host of positive outcomes across childhood and adolescence, including greater social adjustment (Parker & Asher, 1987; Ladd et al., 1997; Ladd & Troop-Gordon, 2003), lower risk for psychopathology (Hirsch & DuBois, 1992; Tanigawa et al., 2011), protection against victimization (Parra et al., 2018; Prinstein et al., 2001), academic achievement (Ng-Knight et al., 2018), and greater physical health (La Greca et al., 2002). Accordingly, it is of great importance for developmental researchers to identify what individual, social, and contextual factors influence children’s ability to successfully navigate social interactions with peers.

To be a compelling and desirable social partner, a child must come prepared to engage flexibly and dynamically with peers across a variety of tasks and contexts. In social contexts, flexibility describes the ability to juggle a variety of concurrent tasks and activities, integrate the plans and perspectives of others with one’s own, and respond to new and often unpredictable turns of events, all at a moment’s notice and without negatively impacting the interaction. By the preschool years, children’s social play already incorporates many complex activities between which children must readily shift, including cooperative problem-solving, sociodramatic play, imitation, and symbolic representation (Leslie, 1987; Lillard et al., 2013; Meltzoff, 1988; Warneken & Tomasello, 2010; Wolfgang et al., 2001). Both the complexity and perceived importance of successful peer interactions increases in middle childhood and early adolescence, as interactions with peers become more frequent, social acceptance becomes more sought-after, and the dynamics of social activities and relationships become more complex (Gummerum & Keller, 2008; Rubin et al., 2006; 2015; Way & Greene, 2006).

Social flexibility may be particularly important for temperamentally shy children. Shyness is typified by fear, wariness, and the tendency to withdraw in response to social novelty and socially evaluative contexts, and is considered a core dimension of temperament in that is heritable, present early in life, and relatively stable across time (Eisenberg et al., 1995; Henderson, 2010; Henderson et al., 2004; Rubin & Coplan, 2004). When engaging with unfamiliar peers, children higher in shyness and social fear exhibit lower levels of social engagement, and also elicit lower engagement from their partners (Thorell et al., 2004; Walker et al., 2015). Shy children are particularly reactive during interactions with unfamiliar peers, exhibiting more negative responses to social exclusion and greater self-consciousness in social contexts (Buzzell et al., 2017; Barker et al., 2018; Walker et al., 2014; Wilson & Henderson, 2020). These patterns of reticence and heightened social sensitivity affect children's adjustment during critical transition periods such as entering school, with shyness being associated with lower academic competence, greater peer exclusion, and less favorable attitudes toward school overall (Coplan et al., 2008; Gazelle & Ladd, 2003; Valiente et al., 2012). At low levels of peer acceptance, shyness is associated with a preference for solitary play, while higher levels of acceptance are associated with positive trajectories of social engagement among shy children, underscoring the importance of understanding the social and cognitive processes that optimize children's early interactions with peers (Sette et al., 2017).

A growing body of research suggests individual differences in how children regulate their attention and behaviour may contribute to the relation between shyness and social anxiety in nuanced ways. Contrary to the intuition that greater self-regulation is unilaterally adaptive for children, greater *inhibitory control* (the ability to inhibit prepotent responses; Miyake et al., 2000) has consistently emerged as a risk factor for social anxiety in shy and behaviourally inhibited children (BI; a developmental precursor to shyness; Buzzell et al., 2021; Eggum-Wilkins et al., 2016; Henderson, 2010; Troller-Renfree et al., 2019b; White et al., 2011). By contrast, *attention shifting* (the ability to engage and disengage one's attention in line with one's goals; Miyake et al., 2000) has been found to protect against the development of social anxiety for shy and BI children (Buzzell et al., 2021; Eggum-Wilkins et al., 2016; Troller-Renfree et al., 2019a; White et al., 2011; Wolfe et al., 2014). Together, these findings suggest shy and BI children able to flexibly shift their attention at will are more likely to develop healthy and adaptive social relationships, while those who excel at inhibiting their impulses may face ongoing social difficulties.

What these findings do not explain, however, is by what *mechanism* these aspects of self-regulation influence shy and BI children's in the moment interactions and longer term developmental trajectories; what is it about how children shift their attention that protects them against later social anxiety?. Past work relating children's self-regulation and social outcomes has done so statistically, measuring each construct in parallel and examining associations between their outcomes (e.g., relating children's performance on a non-social inhibitory control task with parent-reports of their children's social behaviour, as in White et al., 2011). However, going beyond past laboratory studies, it remains unclear *how* attention shifting and inhibition as exercised during dynamic social interactions impact how shy and BI children operate in their social world.

Attempting to shed light on these relations, we proposed a theoretical account (Henderson & Wilson, 2017; expanded in Fox et al., 2021) describing how shy and BI children's attention allocations and regulation may directly interrupt their social behaviour when interacting with peers, thereby influencing the quality of their social experiences (as well as their social partners') and their developmental outcomes in turn. As shy and BI children are highly sensitive to social stimuli and appraisals (e.g., Buzzell et al., 2017), we propose after detecting a salient social event (e.g., a cue it is one's turn to speak, a negative emotional expression in a peer), the attention of shy and BI children is reactively pulled away from shared social goals towards self-conscious processes such as worry, rumination, and hypervigilant monitoring. These momentary (or potentially protracted) 'blips' in the flow of an ongoing interaction, in which a child breaks from the ongoing interaction to attend to these internal experiences, could give rise to feelings of awkwardness, discomfort, and/or apprehension, and the observable behaviours arising from these emotions could fundamentally change the nature of the interaction for both the shy child and their peer. Accordingly, how shy and BI children *regulate* their attention in response to these reactive shifts in attention, viz. engaging in sustained inhibition or flexibly shifting back to the interaction, would bear significantly on the success of their social interactions, and subsequently their feelings of comfort and self-competency when interacting with others in general.

Critically, before we can empirically test these moderating relations, it is essential to establish a means of operationalizing social flexibility as it is manifest in children's real-world social interactions with peers. A promising direction for this research involves examining the response time (RT) of children's turn-taking when engaging in dialogue with peers. Beginning in infancy, humans are highly attuned to turn-taking, with reciprocal communication playing a central role in children's relationship-building and social learning (Albert et al., 2018; Goldstein et al., 2010; Jaffe et al., 2002; Ratner & Bruner, 1978). Infants show evidence of turn-taking in their vocalizations in the first few months of life (Boiteau et al., 2021; Gratier et al., 2015), and by three months are sensitive to delays in communication as short as one second (Striano et al., 2006).

While the RT of conversational turns varies as a function of both context and content (e.g., Trimboli & Walker, 1984), the average RTs observed in adults' turn-taking tend to be remarkably short, averaging between 200ms and 300ms after the preceding utterance (de Ruiter et al., 2006; Levinson & Torreira, 2015; Stivers et al., 2009). Notably, this is faster than the average reaction time associated with even simple cognitive tasks such as picture naming (600ms; Indefrey & Levelt, 2004). Moreover, turn-taking is often "gapless", with turns overlapping with the end of the preceding turn, suggesting that listeners actively prepare their turns in advance and coordinate their turns with the projected end of their partner's speech to ensure fast responding (Heldner & Edlund, 2010; Sack et al., 1974).

The RT of turns in a conversation also conveys meaningful information to its participants. Roberts and associates (2011) found experimentally manipulating the latency of turns in a phone conversation to 600ms or longer leads participants of diverse linguistic and cultural backgrounds (American, Italian, Japanese) to interpret the quality of their conversation more negatively. Consistent with this finding, past studies have noted disconfirmations (communications involving saying no, whether it be answering a questions, refuting a statement, or rejecting an offer or request) are associated with longer RTs, suggesting slower turn-taking may, under certain circumstances, be perceived as a cue to disagreement or discord in an interaction (Kendrick & Torreira, 2015; Stivers et al., 2009).

Building on this work, Templeton and associates (2022) examined the relation between natural variations in turn-taking RTs and adults' perceptions of their connection to their conversational partners. Across a series of studies, they found faster RTs strongly predicted feelings of connection between both strangers (Study 1) and friends (Study 2), with participants' feelings of connection primarily being explained by their partner's RTs rather than their own. The authors also found that when listening to a conversation between other people, participants judged two individuals to be more connected when their turn-taking RTs were faster, suggesting adults use RT as an indicator of social connection for both themselves and others. To our knowledge, however, it has yet to be explored whether turn-taking response time relates to the quality of children's social interactions.

The Current Study: Aims and Hypotheses

While recent work suggests conversational turn-taking is an important index of interaction quality in adulthood (Roberts et al., 2011; Templeton et al., 2022), it remains to be seen whether the same is true for children in middle childhood. The current study addresses this gap by quantifying children's RTs during an unstructured conversation with a previously unfamiliar peer, mimicking the conditions commonly encountered when meeting a new person in the real world. Specifically, the current study examines the relation between turn-taking RT and ratings of social engagement as observed by third-party coders. In line with past adult work (Templeton et al., 2022, Study 3), it was hypothesized that faster turn-taking would be associated with higher ratings of a child's own social engagement (H1) as well as the social engagement of their partner (H2)

Moreover, examining the RTs of children's turn-taking in conversation with peers offers the uniquely tailored opportunity to test a foundational prediction of our theoretical account (Fox et al., 2021; Henderson & Wilson, 2016). We propose when faced with a salient social event such as being prompted to take one's turn in conversation, the attention of shyer children is drawn away from their social goal (that is, sustaining conversation) toward ruminative and self-evaluative processes. As a result, shyer children are predicted to take more time to reallocate their attention back to the conversation and take their turn speaking. As such, another goal of the study was to directly test whether individual differences in shyness relate to the speed of children's conversational turn-taking with peers. In line with our account, it was hypothesized that as trait shyness increases, children will be slower to respond (or have longer conversational RTs) in turn-taking conversation with an unfamiliar peer (H3).

Finally, while we largely focus on how a child's shyness may impact their own behaviour, it is important to consider how a child's shyness may impact their *peer's* behaviour. Our account contends a shy child's attentional preoccupations may diminish the quality of their social exchanges with peers and make them less appealing social partners. As such, building on past findings suggesting conversational response time is an important predictor of dyadic social connectedness (Templeton et al., 2022), it was hypothesized as a child's shyness increases, their partner response times in turn-taking conversation would also increase (H4).

Methods

Participants

Sixty-two typically-developing children between the ages of 9 and 12 clustered into 31 dyads participated with their parents as part of a study of temperament, cognition, and social development. Data collection was interrupted by the onset of the Covid-19 pandemic, resulting in a smaller sample size than the a priori goal of 60 dyads. Of the 31 dyads participating in the study, participants in three dyads (all boys) were silent for the entire duration of the period being behaviourally coded (described below), and thus were not included in the analyses pertaining to these periods. These children did not differ from rest of the sample with regard to age or self-reported shyness, *p*s > .05. As such, the final sample for the main analyses consisted of 56 children spread across 28 dyads (M_{age} = 10.20, SD = 0.84, 36 girls).

Ethnic demographics of the final sample were as follows: 78.6% White, 5.4% East Asian, 1.8% Black, 1.8% Latin American, and 12.5% mixed race/other). Parent education levels were varied (maternal/paternal education: 3.6%/5.4% high school, 10.7%/10.7% some university/college, 12.5%/ 16.1% 2-year college, 41.1%/32.1% 4-year university, 32.1%/35.7% advanced or professional degree). Annual household incomes above average (median for the Waterloo region: $77,263; Statistics Canada): 1.8% of families reported earning $25-$50k in the past year, 17.9% earning $50-$75k, 26.8% earning $75-$100k, 51.8% earning more than $100k, 1.8% choosing not to disclose. Participants were recruited through community events, social media (e.g., Facebook, Kijiji) and by letters distributed to local schools. For reasons related to other measures included in the wider study but not described here, eligibility criteria included no formal diagnosis of attention deficit hyperactive disorder or autism spectrum disorder.

Materials

The Child Shyness Questionnaire (CSQ). The CSQ (Crozier, 1995) is a 26-item self-report questionnaire assessing the behavioral, affective, and physiological manifestations of children's shyness. For each item, children respond with no, sometimes, or yes (scored as 0, 1, or 2, respectively). A total of 21 items probed the experience of shyness directly, including ‘‘I find it hard to talk to someone I don't know,” ‘‘I go red when someone teases me,” and ‘‘I feel shy when I am the center of attention.” An additional 5 reverse-scored items assessed children's inclination toward more exuberant behavior, including ‘‘I enjoy singing aloud when others can hear me” and ‘‘I say a lot when I meet someone for the first time.” Responses were summed to yield a continuous shyness score ranging from 0 to 52, with higher scores indicating higher levels of shyness. In the current sample, the internal consistency of the CSQ items was high (α = .88).

Across the sample, three children (*N* = 3) did not complete the CSQ: one opted not to complete the questionnaire, while two did not complete the visit during which the CSQ was administered due to the onset of the COVID-19 pandemic. The results of a Missing Completely at Random test (MCAR; Little, 1988) suggest data were missing at random, χ^2 (2, *N* = 55) = .055, *p* = .973. As such, multiple imputation was used to impute missing data. The multiple imputation function in IBM SPSS Statistics (Version 28.0) generated 5 datasets including all relevant analysis variables. Children with imputed values did not differ from other children with regard to CSQ score, *t*(4.27) = -0.037, *p* = .988, gender, *t*(53) = -1.11, *p* = .270, or age, *t*(53) = .725, *p* = .471.

Procedure

Participation in the study entailed two visits: an individual visit in which participants completed a series of tasks and questionnaires alone, and a dyadic visit in which participants completed both a series of dyadic tasks in addition to a handful of individual tasks completed alone. Scheduling of the visits occurred at participants' convenience (87.5% completing the individual visit first), with parents completing a series of questionnaires regarding their child's temperament and social development at their first scheduled visit. Behavioural indices of interest are taken from the dyadic visit, described below.

To ensure participants were truly unfamiliar to one another upon their first meeting during the dyad visit, one participant in each visit was scheduled to arrive 15 minutes before the other and remained in a separate room until the dyadic activities were set to begin. While separated, participants and their parents provided informed assent and consent, respectively.

Next, participants put on mobile physiology recording equipment with the assistance of a parent and quietly watched a 3.5-minute nature video while baseline physiological readings were recorded. Physiological data were recorded as part of the broader study but are not discussed further as they have no bearing on the research questions at hand. The participant scheduled to arrive early also completed three short cognitive tasks administered on an iPad while their peer provided informed consent; the participant arriving later completed their iPad tasks after the dyadic portion of the visit.

Following these preparatory steps, participants were introduced to their dyadic partner: an unfamiliar peer of the same gender and within 6-months of their own age. The dyadic portion of the visit took place in an observation room equipped with three video cameras and a ceiling-mounted microphone, monitored from an adjacent room. Participants were seated at a table across from one another and instructed to 'get to know each other' for five minutes, with no additional guidelines or structure for their interactions (Usher et al., 2018). Following this interaction, dyads completed a series of other tasks as part of the broader project. At the end of the laboratory session, all participants were debriefed, remunerated, and thanked for their participation.

Behavioural Coding

Participants' interactions were coded in two different ways by two independent pairs of coders: one set of coders focused specifically on *classifying children's utterances*, while the other focused more globally on children's *social engagement*. To ensure reliability within each pair of coders, several dyads were coded as practice over the course of multiple weeks prior to beginning the actual coding period. Over the course of the coding period, a random sample of nine dyads (approximately one third of the full sample) was coded by both observers in each dyad to compute reliability, with weekly calibration checks and discussions to minimize coder drift and resolve disagreements in overlapping videos.

Classifying children's utterances. Two trained observers (the lead author and a research assistant) coded the communicative utterances of participants in each dyad using event-based coding in Mangold INTERACT (Mangold, 2020). The coding scheme was adapted and expanded from Usher and associates (2018). Each communicative utterance was categorized as either a *share, seek, response*, or *reaction* (examples below; all mutually exclusive). *Shares* were broadly defined as any utterance in the form of a statement offering information such as the participants' thoughts ("I wonder why we are here"), feelings ("I'm hungry"), observations ("That bookshelf is crooked"), or opinions ("I like hockey"). *Seeks* were defined as utterances seeking to elicit information from the peer ("What school do you go to?"), while *responses* describe the subsequent offerings of information in response to a Seek. *Reactions* describe any short (i.e., one or two word) utterances offered in response to an utterance by one's peer relaying acknowledgement, affirmation, and/or active listening (e.g., "Yeah", "Oh wow", "That sucks"). Utterances were only coded as reactions when they occurred in isolation (e.g., "Yeah." followed by silence). When reactions occurred as part of a broader utterance by the participant (e.g., "Yeah, I really hate gym class too"; "Oh wow, what did you say then?"), the reaction would be subsumed into the other, more substantial code (e.g., "Yeah, I really hate gym class too" [Share];

"Oh wow, what did you say then?" [Seek]). The following is a hypothetical example of a simple exchange containing each unique code:

Child A: "What school do you go to?" [Seek]

Child B: "Applegate Middle. [Response] You?" [Seek]

Child A: "Oh cool. Orangeville Academy." [Response]

Child B: "Nice." [Reaction]

Child A: "Yeah. [Reaction]

Child B: "Do you like football?" [Seek]

Child A: "I love football." [Response]

In addition to coding utterances based on their content, the onset and offset of each utterance was recorded with frame-by-frame accuracy from the 30 frames-per-second video/audio recordings. To differentiate between the RTs associated with turn-taking within a conversation and the longer periods of silence occurring across lapses in conversation, utterances were further operationalized on the basis of RT as *turns*, *initiations*, *interruptions,* or *successive utterances,* presented visually in Figure 7. RT for each utterance was computed by subtracting the onset time of a participant's utterance from the offset time of their partner's preceding utterance (vertical dashed line). *Turns* were defined as any utterance by a participant occurring within 5 seconds of the end of a preceding turn by their dyadic partner. In other words, turns reflect the active speaker within an ongoing conversation changing from one partner to the other. The RT for a turn could be positive or negative, with negative RT indicating the participant began their utterance prior to their partner finishing speaking (exemplified by the turquoise line in Figure 7; see caption for an example). Negative turn-taking RTs are a common occurrence in everyday speech and are indicative of engagement (Heldner & Edlund, 2010; Sack et al., 1974).

Initiations (purple line) were defined any utterance occurring after more than 5 seconds of silence, regardless of who spoke last; that is, after a lapse in conversation has occurred and conversation needs to be restarted. *Interruptions* (pink line) were defined as any utterance by a participant that both start *and end* while their partner is speaking, and thus cannot be conceived as a turn in conversation. Finally, *successive utterances* (yellow line) were defined as sequential utterances by the same participant occurring within 5 seconds of each other (i.e., too quickly to be coded as an initiation) but nonetheless being sufficiently distinct as to warrant a unique code. For example, after responding to a seek (a valid turn) and a short pause, the same child poses a question on an unrelated topic. Interrater reliability was adequately high ($\kappa = .78$).

Social engagement. An independent pair of trained observers (a research associate and a research assistant, neither involved with the coding of turn-taking) provided ratings of each participant's individual, global levels of *openness*, *social ease*, and *conversational appropriateness* using event-based coding in Mangold INTERACT (Mangold, 2020). *Openness* ratings ranged from 1 (participant is "closed off" and remains actively disengaged) to 5 (participant encourages ongoing engagement through their behaviour and body language) and encompassed specific factors such as eye contact, body orientation, and gestures communicating attentiveness (e.g., nodding). *Social ease* ratings ranged from 1 (participant is visibly anxious and uncomfortable) to 5 (participant is visibly content and at ease), capturing the extent to which a child's emotional expressions and behaviours conveyed ease or discomfort (e.g., nervous laughter, physical tension). *Conversational appropriateness* ratings ranged from 1 (consistently inappropriate) to 5 (consistently appropriate) and pertained to whether the topics selected for conversation were suitable for the context (e.g., did the child overshare personal details) and whether the conversational load was equitably shared with the partner. The three scales

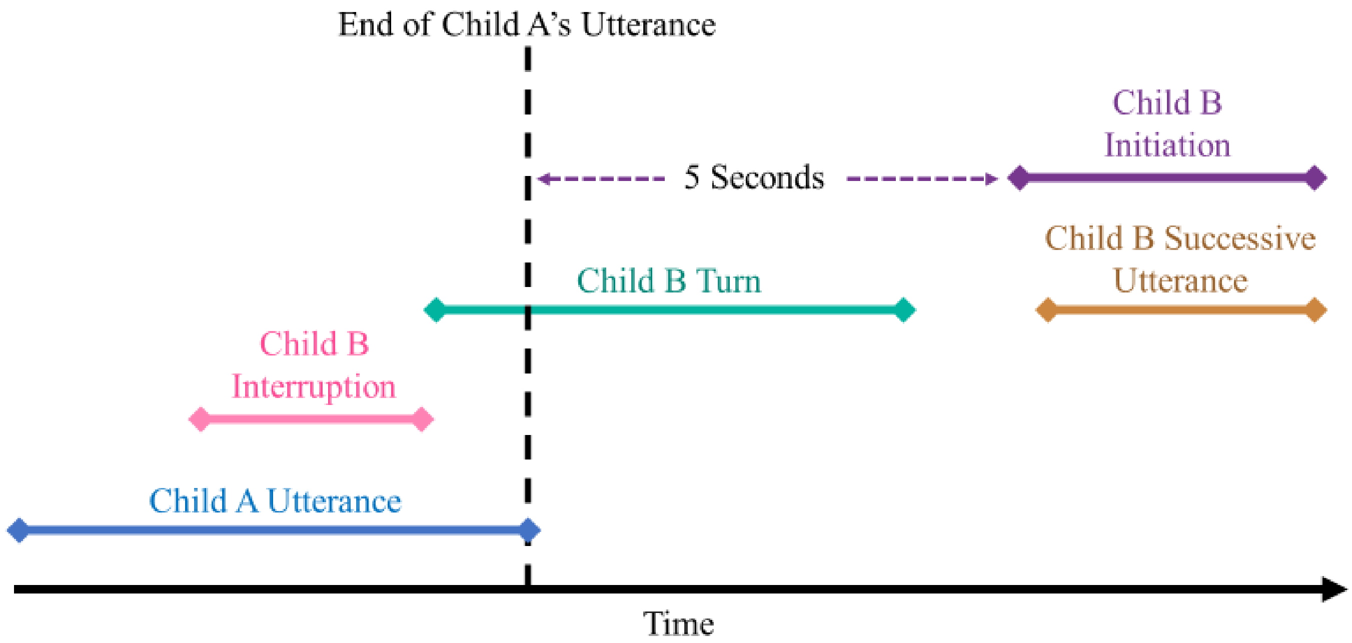

Figure 7. Visual representation of how utterances were operationalized on the basis RT. The blue bar represents the initial utterance of one child in a dyad (Child A), while the four remaining bars represent how subsequent utterances from the other child (Child B) would be categorized. As an example, as the onset time of Child B's turn (turquoise) preceded the ending of Child A's original utterance (blue), the RT for that turn would be negative (e.g., -140ms).

were highly correlated (ranging from r = .508 to r = .729, ps < .001), and thus a total *Social Engagement* score ranging from 3-15 was calculated from the sum of these three scores. Interrater reliability was adequately high (α = .84).

Analytic Strategy

All analyses were conducted using SPSS 28.0.1 (IBM, 2021). As the dataset consists of observations of individuals clustered within dyads, dyads were indistinguishable (i.e., there were no asymmetries in the roles or factors differentiating the two members of a given dyad), and hypotheses concerned both actor effects (e.g., a child's shyness predicting their own RTs) and partner effects (e.g., a child's shyness predicting their partner's RTs), the use of multilevel modeling (MLM) to estimate Actor-Partner Interdependence Models (APIMs) was identified as the most direct means of addressing the study's research questions (Campbell & Kashy, 2002; Kenny et al., 2006; West et al., 2008). The degree of nonindependence of the outcome variables in each model was assessed through intraclass correlations (ICCs; Kenny et al., 2006).

To investigate hypotheses 1 and 2, an APIM model was run with child (H1) and partner (H2) turn-taking RT predicting social engagement. To investigate hypotheses 3 and 4, another APIM model was run with child (H3) and partner (H4) shyness predicting turn-taking RT. Predictor variables were grand mean centred before being entered into their respective models.

Results

Descriptive Statistics

Across the sample, there was notable individual variability in both shyness, $M = 20.75$, $SD = 9.73$, and social engagement, $M = 11.11$, $SD = 1.78$. Bivariate correlations between shyness and social engagement were nonsignificant, $r = .133$, $p = .328$. Descriptive statistics summarizing the frequency and proportion of children's utterances across the entire sample are presented in Table 3 and 4 and Figures 8 and 9. Figure 8 presents participants' utterances as a function of their content. Approximately half of all children's utterances were in the form of shares (personal facts, anecdotes, observations, etc.), while the other half were distributed between seeks, responses to seeks, and reactions.

Figure 9 presents children's utterances operationalized on the basis of RT. Approximately 72% of utterances were classified as turns in conversation, reflecting shifts in the conversational spotlight from one child to the other. Another 16% of utterances were classified as successive utterances, indicating the same speaker spoke twice in a row after a short pause and/or topical

Table 3. Average frequency of each type of utterance, broken down by content (*N* = 1847).

	Shares (*n* = 904)	Seeks (*n* = 349)	Responses (*n* = 309)	Reactions (*n* = 285)
Mean (*SD*)	15.95 (*6.20*)	6.24 (*3.93*)	5.87 (*3.82*)	4.64 (*5.00*)
Median	17	5	4	3
Range (*Min*, *Max*)	25 (*5*, *30*)	16 (*0*, *16*)	16 (*0*, *16*)	23 (*0*, *23*)

Table 4. Average frequency of each type of utterance, classified by response time (*N* = 1198).

	Turns (*n* = 1323)	Initiations (*n* = 146)	Interruptions (*n* = 81)	Successive Utterances (*n* = 297)
Mean (*SD*)	23.42 (*7.13*)	2.55 (*2.16*)	1.45 (*2.33*)	5.27 (*4.01*)
Median	24	2	0	5
Range (*Min*, *Max*)	32 (*10*, *42*)	8 (*0*, *8*)	9 (*0*, *9*)	19 (*0*, *19*)

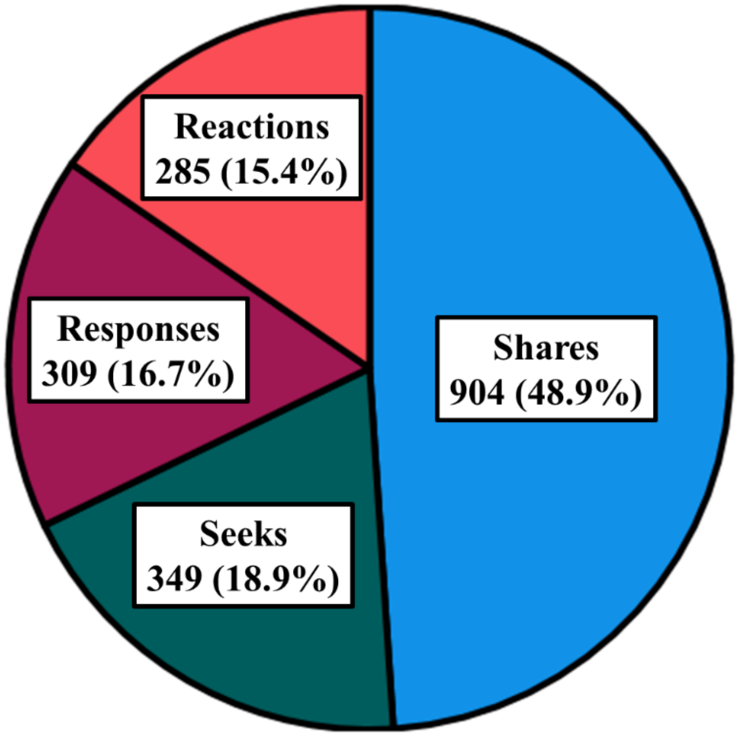

Figure 8. The frequency and proportion of children’s utterances classified by content.

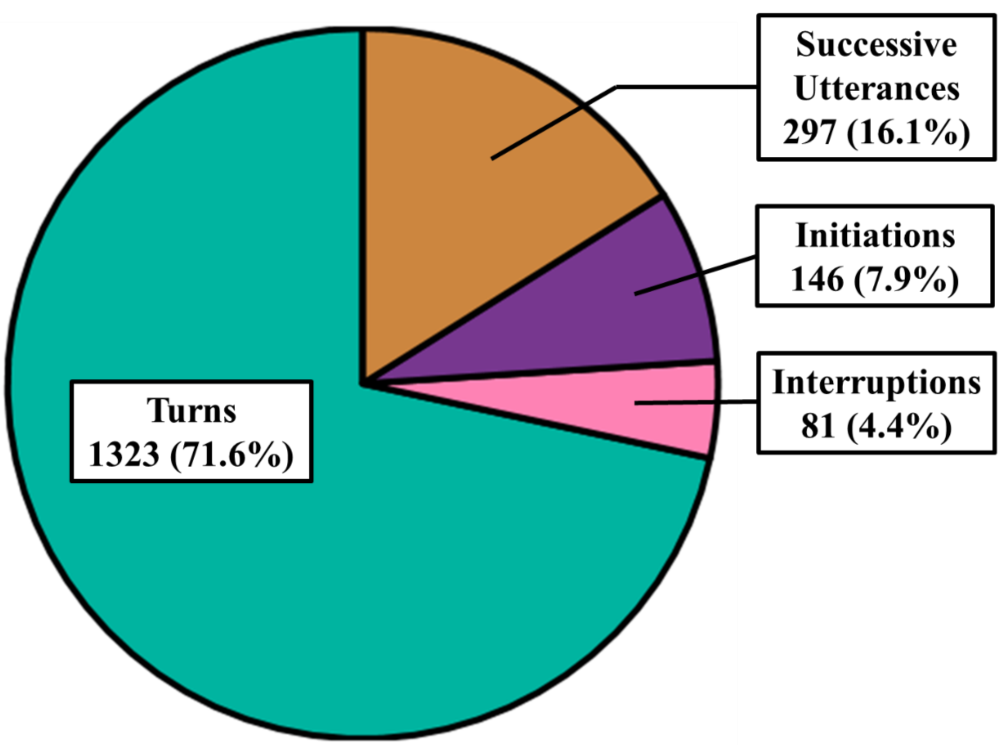

Figure 9. The frequency and proportion of children’s utterances as classified by RT.

shift. The remaining utterances were divided between initiating conversation following a prolonged lapse (8%) and interruptions while the other participant was speaking (4.4%).

Specifically focusing on children's turn-taking, the distribution of children's RT when taking turns in conversation is presented in Figure 10. Mean turn-taking RT was 707 ms with a standard deviation of 107 ms, with a median RT of 386 ms. The distribution was moderately positively skewed (1.287), reflecting the onset of children's turns more often beginning after the end of the preceding utterance from their peers.

In summary, children's conversations were predominantly characterized by reciprocal turn-taking, with the sharing of personal information accounting for half of all utterances and the remaining being split between asking/responding to questions and reacting to comments from one's peer.

Hypothesis Testing

Turn-Taking RT Predicting Social Engagement. Prior to running an APIM model with social engagement as the outcome variable, an intercept-only model was run to assess the proportion of variance in social engagement occurring at the dyad-level. The ICC was .54 (Wald Z = 4.81, $p < .001$), indicating 54% of the variability in social engagement occurred at the dyadic level and supporting the use of MLM.

Having established the nonindependence of the data, an APIM model was run with child (H1) and partner (H2) turn-taking RT predicting social engagement. Consistent with H1, children's turn-taking RT was negatively associated with their own social engagement, $b = -2.09$, $t = -3.52$, $p < .001$, 95% CI [-3.29, -0.90]. For every 1000ms increase in children's RT (i.e., for every second they were slower to respond), their social engagement score decreased by 2.09.

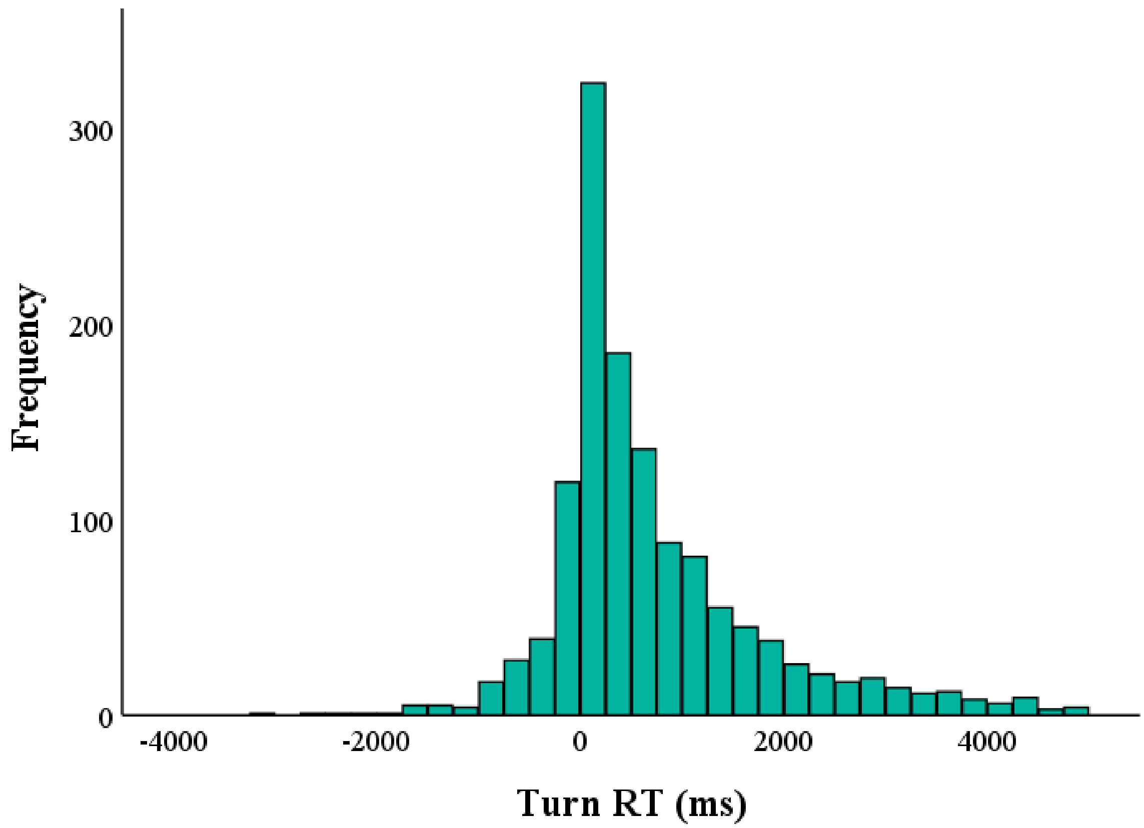

Figure 10. Histogram depicting the distribution of participants' turn-taking response time (ms) across the sample (*N* = 1232).

Turning to potential partner effects, H2 was not supported, although there was a marginal effect of children's turn-taking RT on their partner's social engagement, $b = -1.17$, $t = -1.96$, $p = .055$, 95% CI [-2.36, .025]. For every 1000ms increase in children's RT, their partner's social engagement score decreased by 1.17.

Shyness Predicting Turn-Taking RT. Prior to running an APIM model with turn-taking RT as the outcome variable, an intercept-only model was run to assess the proportion of variance in turn-taking RT occurring at the dyad-level. The ICC was .43 (Wald Z = 3.74, $p < .001$), indicating 43% of the variability in turn-taking RT occurred at the dyadic level and supporting the use of MLM.

Having established the nonindependence of the data, an APIM model was run with child (H3) and partner (H4) shyness predicting turn-taking RT. Contrary to H3, children's shyness was unrelated to their own turn-taking RT, b = -0.004, t = -0.87, p = .388, 95% CI [-0.01, 0.01]. There was, however, an association between children's shyness and their partner's turn-taking RT, but in the opposite direction than predicted in H4: as children's shyness increased, their partner's turn taking RT *decreased* (i.e., got faster), b = -0.011, t = -2.18, p = .035, 95% CI [-0.02, 0.00]. For every unit increase in shyness in a child's social partner, the child's own turn-taking RT decreased (i.e., got faster) by 11ms.

Discussion

To our knowledge, the current study is the first to empirically examine children's response time when interacting with a peer during a conversation as an index of social engagement. The primary goals of the current study were 1) to evaluate children's turn-taking response time as a predictor of social engagement (for both themselves and their partner) as reported by third party observers, and 2) to examine whether children's self-reported shyness was related to their own (and their partners') response time in conversation with an unknown peer in a novel context.

Supporting H1, turn-taking response time was negatively related to observed social engagement, such that faster turn-taking (i.e., lower RTs) was associated with higher scores on a composite score encompassing observers' impressions of children's global openness, social ease, and conversational appropriateness. While conclusive evidence supporting that children's response time impacted their peer's social engagement (H2) was not found, a marginal effect was detected, highlighting the need for future research to determine whether this relation is spurious or supporting the relation between children's turn-taking RT and their peer's engagement. There was no indication that children's shyness was related to their turn-taking RT, failing to support H3. However, there was an association between children's shyness and their *partner's* turn-taking RT, but in the opposite direction as predicted by H4.

Turn-taking response time and social engagement

The current study examine children's turn-taking response time in relation to the outcome of children's peer interactions. Children's turn-taking response time was remarkably fast, with a mean RT of 707ms. This is on average slower than the 200-300ms found in past adult studies (e.g., Stivers et al., 2009; Templeton et al., 2022), reflecting the positive skew of the distribution of scores (see Figure 10). By contrast, the median RT (386ms) was closer to the adult mean. Together, these findings suggest that while children's turn-taking behaviour was remarkably adult-like, there may be specific social events occurring in the run of a conversation that interrupt the fluidity of children's responding. Indeed, these outlying datapoints in the tail of the distribution may represent critical instances in which children are unsure how to proceed in a conversation and their attentional flexibility is truly put to the test. Future research is needed to disentangle what specific occurrences may underlie these instances of delayed responding, how trait-level individual differences may explain some of the variability in children's responses to these events, and ultimately how these unique cases may predict the outcomes of children's interactions.

In line with our predictions, faster turn-taking was associated with higher ratings of observed social engagement, replicating past work with adults (Templeton et al., 2022). Behavioural coding of participants' social behaviour revealed children engaged in a variety of communicative behaviours, the vast majority occurring as part of turn-taking conversation. There was also significant variability in both the frequency and latency of children's turn-taking, with averages response times consistent with those from past studies with adults (e.g., Levinson & Torreira, 2015; Stivers et al., 2009; Templeton et al., 2022). Together, these findings support the validity of response time as a measure of social interaction quality in middle childhood, laying the groundwork for future studies using response time as a nuanced index of children's social behaviour *in vivo*.

The most frequent produced type of communication, accounting for approximately half of all coded utterances, was the sharing of information in the form of statements (e.g., passing observations, personal anecdotes, self-disclosures of thoughts and opinions). The predominance of shares in children's conversations highlights why quick and flexible thinking is central to dynamic engagement with peers. That is, while replying to a seek from a peer is relatively straightforward (the topic of conversation and cue to speak having been clearly laid out), the response to a share can assume many forms and branch off in a variety of different directions: the reciprocal sharing of information about oneself, a follow-up or clarification question, a pivot to a new topic, etc. Accordingly, to avoid the conversation stagnating and lapsing into an awkward silence, children must be readily able to select and engage a contextually appropriate response at a literal moment's notice. The significant relation between children's turn-taking response time and observed social engagement may thus reflect the extent to which they are "tuned in" to the interaction and able to effectively sustain conversation with their peer. Future work experimentally examining the relations between specific conversational prompts (e.g., shares vs. seeks) and turn-taking response time, as well as the potential moderating influence of other individual/contextual factors (shyness, executive control, the perception that one is being evaluated) would shed more nuanced light on the specific challenges children face when interacting with peers.

Notably, reciprocal turn-taking in the sharing of personal information may be as (if not more) important to the fostering of interpersonal connections than simply the quantity of information being shared. Research with unfamiliar adults by Sprecher and associates (Sprecher & Treger, 2013; Sprecher et al., 2015) revealed the self-disclosure of personal information in a back-and-forth manner predicted greater ratings of closeness, enjoyment, and perceptions of being liked than did self-disclosure in two longer blocks of sharing, despite participants in both conditions having equal time to share. Future work should seek to explore how the structure and sequencing of children's communications predicts their subjective feelings of liking and being liked.

Children's response time in conversation was also found to be a marginally significant predictor of their *partners'* social engagement. If this is a true rather than spurious association, it is consistent with past work suggesting faster turn-taking fosters connection and engagement with one's interlocutors (Roberts et al., 2011; Templeton et al., 2022), and supports the idea that children's dynamic interactions with peers is a central part of what makes them an appealing social partner (Fox et al., 2021; Henderson et al., 2017). While the premature ending of data collection due to COVID restrictions limited our sample size and therefore the power to detect potential effects, future work should seek to confirm how the latency of children's turn-taking impacts the engagement of other children with whom they interact.

The measure of social engagement used in the current study was generated from third party observations, in which a team of coders provided global assessments of the openness, social ease, and appropriateness of each participant. The division of coding responsibilities between two independent teams ensured the coders gauging children's social engagement were not directly attending to children's response times nor aware of the study's predictions regarding response time and social engagement. That said, an important future direction for the current study will be to evaluate how turn-taking response time relates to children's self-reported perceptions of the quality of their interactions with others. When meeting a peer for the first time, the speed with which a child converses may play a central part in the impression they leave on their peer, implicitly communicating how fun they are as a playmate or how eager they are to forge a friendship. Additionally, children may use their partner's response time as a cue to how appealing they are *themselves* as social partners. This implicit feedback may be particularly important for shyer children insofar as they are more sensitive to social evaluation and may struggle with lower self-esteem. Building on the current work, future research should seek to incorporate children's perspectives to evaluate whether turn-taking response time impacts a) children's perceptions of their peer's likeability, b) children's perceptions of their own likeability in the eyes of their peer (i.e., their *metaperceptions*; Kenny & DePaolo, 1993; Usher et al., 2018), and c) children's feelings of closeness and connection with their peer.

Shyness and turn-taking response time

Contrary to our predictions, shyness was not related children's turn-taking response time. This null finding is surprising given the patterns of reticence with which shyness is associated in early and middle childhood (e.g., Degnan et al., 2011; Walker et al., 2014), although several factors may account for this result. Rather than impacting the speed of children's turn-taking in general, the effect of shyness on children's response times may be more nuanced. Both shy and exuberant children alike likely experience feelings of awkwardness when meeting another child alone in a one-on one situation, leading them to stick to more rehearsed, all-purpose small-talk that elicits similar turn-taking response times from all children. Instead, it may be the effects of shyness only emerge once conversation drifts away from rehearsed ice-breakers to more personal or playful dialogues, after the initial universal awkwardness of meeting someone new subsides. Indeed, it may not be the first meeting between new acquaintances but rather the *second or third* that is most informative, when the bonds of friendship and familiarity should be cementing and the hurdles imposed by shyness come to the fore. Future research should consider how temporal dynamics of children's turn-taking conversation play out over several interactions, as well as examining how the superficiality of the content of children's communications influence children's turn-taking response time as a function of shyness.

Beyond a child's own level of shyness, it may also be important to consider how a shy child's behaviour is influenced by temperamental characteristics of their partner. Paired with a more exuberant partner who can steer the conversation, shyer children may be more able to engage in fast and seamless turn-taking (Sosa-Hernandez et al., 2022). Alternatively, shyer children might feel more comfortable engaging with partners similar in their level of shyness, while more outgoing partners might be intimidating and lead shyer children to withdraw. Actively pairing children with varied levels of shyness (e.g., high-high, high-low, low-low) would be an exciting next step for this research. Moreover, other partner characteristics including conscientiousness, empathy, or prosociality may also play important roles. While our analyses accounted for dyadic clustering of data, the small sample size of the current study precluded more complex analyses involving partner- or dyad-level factors. Future studies should strive to consider actor-, partner-, and dyad-level characteristics in tandem to provide a more holistic view of the shyness and other temperamental characteristics in children's social interactions.

Ultimately, as alluded to above, the sample size of the current study may not have been large enough for associations between shyness and response time to have emerged, data collection having been halted prematurely due to the Covid-19 pandemic. Specifically, the limited number of children at either end of the shyness distribution (i.e., high shy vs. low shy) may have obscured the relation between shyness and response time. As such, future studies with larger samples are necessary to conclusively determine whether timely turn-taking plays a role in the social interactions of shy children.

Other considerations and future directions

The current study focused specifically on children's verbal communication when engaging with an unknown peer. However, social information communicated through other means not encompassed by the current coding scheme may also have significant implications for children's turn-taking. For example, when listening to a peer's anecdote, nonverbal behaviours such as sustained eye-contact, nodding, smiling, and laughing may play an important role in communicating affirmation and acceptance, as well as facilitating a healthy back-and-forth in conversation. Expanding on the current findings, future work should consider how nonverbal social behaviours interact with explicit verbal communication to contribute to the speed and quality of children's turn-taking and in turn, their resulting feelings of social connection.

Notably, the three dyads excluded from analyses for remaining silent for the 5-minute period documented were all boys. Past work has identified stronger relations between shyness and a variety of internalizing problems including anxiety, loneliness, and lower self-esteem in boys (Colder et al.; 2002; Coplan and Weeks, 2009; Morison & Masten, 1991). Specifically with regard to differences in communication styles, Mewhort-Buist and associated (2020) noted girls (particularly shy girls) are more likely to endorse using prosocial communicative strategies than boys, which may set them up for success when breaking the ice with a new peer. While the current study is not sufficiently powered to examine potential gender effects, there may be meaningful gender differences in how children respond to the social demands of interacting with a new peer in an unstructured setting, particularly among shy children.

Conclusion

In sum, the current study is the first (to our knowledge) to examine conversational response time as an index of flexibility and engagement in children's communications with their peers. Building on past work with adults (e.g., Templeton et al., 2022), the current study highlights the relation between fast, flexible responding and social engagement, as well as taking important first steps in relating individual differences in temperament to subtle changes in behaviour that could have meaningful impacts on children's social development (Fox et al., 2021, Henderson & Wilson, 2017). Moreover, by developing a new, ecologically valid approach to analyzing the moment-to-moment processes in children's dyadic social behaviour, the current study paves the way for new research examining how individual and environmental factors influence the quality of children's social interactions in real-world situations, such as when making a new friend.

Chapter Four: Mind wandering and executive dysfunction predict children's performance in the metronome response task

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Introduction

Mind wandering is a universal aspect of the subjective human experience, accounting for significant portions of waking life and occurring in a variety of contexts (Kane et al., 2007; Killingsworth and Gilbert, 2010). While specific operational definitions vary, mind wandering (also known as task-unrelated or stimulus-independent thoughts) broadly refers to attentional engagement with internal thoughts unrelated to one's immediate surroundings or ongoing task demands (Smallwood & Schooler, 2006). Experimental work has identified various factors that increase the frequency of mind wandering including negative mood (Smallwood, Fitzgerald, Miles, & Phillips, 2009; Smallwood, O'Connor, Sudbery, & Obonsawin, 2007), provocation by distractors (Vannucci, Pelagatti, & Marchetti, 2017), and the self-perceived perpetration of errors (Cheyne, Solman, Carriere, & Smilek, 2009). Critically, reports of mind wandering in experimental settings relate to the frequency of mind wandering in the real-world, supporting the ecological validity of in-lab studies of the phenomenon in adults (Kuehner, Welz, Reinhard, & Alpers, 2017; McVay, Kane, & Kwapil, 2009).

The experimental study of mind wandering typically involves examining participants' behavioral task performance in conjunction with experience-sampling via 'thought probes': periodic prompts throughout a task asking participants to report on their subjective mental states in the time leading up to the probe. By comparing participants' behavior prior to reports of mind wandering (as indexed by error rates, response times, etc.) with the same behaviors prior to reports of being on-task, the impacts of mind wandering on cognition and behavior can be explored. Further, by linking reports of mind wandering to changes in observable behavior, participants' ability to report on this subjective experience under varying conditions can be validated. Frequently used tasks include the Choice Reaction Time Task (CRT), in which participants make simple judgements in response to infrequent target trials (e.g., whether a target number is odd or even; Smallwood, Ruby, & Singer, 2013), and the Sustained-Attention-to-Response Task (SART), a go/no-go task in which participants must sporadically withhold initiating a keypress (the prepotent response to non-target trials) when presented with infrequent targets (Robertson et al., 1997; Smallwood et al., 2004).

Mind Wandering in Children and Adolescents

While the vast majority of research into the experience of mind wandering has centered on adults, an emerging body of developmental work suggests school-age children similarly experience, and can reliably report on, mind wandering in experimental settings. Mrazek and associates (2013) found that the self-reported tendency to mind wander in day-to-day life, predicted the frequency of middle- and high-schools students' task unrelated thoughts in a reading task, which subsequently predicted overall comprehension levels. Ye and associates (2014) examined 8- to 13-year-olds' experience of past- and future-oriented task-unrelated thoughts while completing a choice reaction time task (Study 2a) and a working memory task (Study 2b). Children reported being on-task more frequently than mind wandering and having more future- than past-oriented thoughts, with the frequency of future-oriented thoughts positively correlating with self-reported trait-level mind wandering. Notably however, McCormack and associates (2019) found that only adults exhibited a future-oriented bias when mind wandering during a coloring task, with a third of the youngest group of children (6- to 7-

year-olds) reporting no future-oriented thoughts whatsoever, suggesting that the temporal focus of children's occurrent thoughts may evolve over the course of development.

In a later study examining the validity of children's reports of mind wandering, Zhang and associates (2015) administered a simplified SART to 9- to 11-year-old children. Reports of mind wandering during the task were positively related to error rates (failures to withhold keypresses), omissions (withheld keypresses in response to non-targets), anticipations (keypresses in response to non-targets under 100 ms, thought to reflect impulsive responding), and reaction-time variability. Critically, however, these relations were only found among children with negative views of daydreaming, as indexed by a short self-report questionnaire. By contrast, among children appraising daydreaming as a generally positive experience, there were no relations between reports of mind wandering and any of the behavioral indices studied. This finding suggests there is a good deal of between-individual variability in the experience and validity of children's reports of mind wandering and underscores the importance of considering other within-person characteristics that moderate these relations.

One variable that may account for significant individual differences in the experience of mind wandering (in both children and adults) is executive functioning (EF), often considered the core of self-regulation (e.g., Baumeister & Heatherton, 1996; Hofmann et al., 2012). Ye and associates (2014) note that the overall frequency of task-unrelated thoughts was negatively related to performance in a working memory task while it was unrelated to CRT performance, suggesting that the level to which mind wandering interferes with children's performance may vary across tasks as a function of task demands. Keulers and Jonkman (2019) probed 9- to 11-year-olds' thought contents during a classroom listening task, as well as during and after a battery of EF tasks. Children's overall frequency of mind wandering was found to be similar across contexts (20-25% of probes). With regard to individual differences, lower levels of inhibitory control was related to more frequent mind wandering in the classroom listen task and following (but not during) the EF battery, while lower shifting ability only related to the increased frequency of retrospective reports of mind wandering following the EF battery (Keulers & Jonkman, 2019). Notably, in contrast to findings from Ye and associates (2014), there was no observed relation between mind wandering and working memory task performance. Finally, in a study with participants ranging from ages 12 to 27, Gyurkovics, Stafford, and Levita (2020) found that both trait mind wandering and task-unrelated thought frequency in the SART increased with age, and that the frequency of mind wandering (with awareness, specifically) was negatively related to temporal interference effects in a Flanker task. This suggests individual differences in the propensity to mind wander (at least some particular forms of mind wandering) may relate to children and adolescents' ability to meet the executive demands of a given situation.

Contributions of the Current Study

These developmental studies are some of the first forays into the study of mind wandering in children and provide a strong foundation for future research. There remain however some open questions regarding the extent to which children's subjective experience of mind wandering (and their ability to reliably report on this experience) mirrors that of adults. In the adult mind wandering literature, the most prominent means of validating participants' introspective reports has been correlating reports of mind wandering with error rates, with errors most typically occurring in response to infrequent target trials (e.g., no-go trials in the SART, incongruent trials in the Flanker). This is likewise true of past child studies (e.g., Keulers & Jonkman, 2019; Ye et al., 2014; Zhang et al., 2015). An outstanding methodological concern noted by Seli and associates (2013) is that given the standout nature of target trials (particularly those resulting in the commission of an error), these infrequent task events may actually provoke incidence of mind wandering, thereby confounding their use as a measure of more spontaneous, task-unrelated mind wandering. Given that the study of mind wandering children is a burgeoning field of research, the validity of children's reports of mind wandering has (to our knowledge) yet to have been examined in task contexts that do not feature conspicuous target events that may provoke response errors or could otherwise instigate mind wandering.

The current study adds to the extant literature by incorporating an alternative mind wandering task from the adult literature: the Metronome Response Task (MRT; Seli et al., 2013). The demands of the task are simple: press a button on the keyboard in sync with a long, unwavering series of tones from a metronome. The (literal) monotony of the task is only interrupted by the occasional presentation of thought probes. As such, the MRT is devoid of conspicuous task events that could influence participants' experience of mind wandering (e.g., infrequent target trials requiring altered behavior), precludes the possibility that children could readily recognize they had perpetrated an error (e.g., failing to withhold a response in the SART), and (by virtue of its tedium) provides ample opportunity for mind wandering. Rather than relying on gross indices such as the commission of errors, the synchrony and rhythmic variability with which keypresses are made in concert with the tones serve as more continuous behavioral correlates of mind wandering. Seli and associates (2013) found that adult participants exhibited greater variability in keypresses preceding reports of mind wandering than reports of being on-task (a finding recently replicated by Anderson et al., 2021). With respect to validating new research methodologies, it is of great interest to developmental researchers to establish the conditions under which children can provide valid reports of their subjective experience. Doing so would open up new possibilities for the use of experience-sampling with children, allowing researchers to assess dynamic cognitive processes such as goal-motivation and uncertainty *in situ* in experimental contexts.

As such, building on past work, the primary goals of the current study were to examine both the frequency and the validity of children's reports of mind wandering in a boredom-inducing task low in external stimulation and with no obvious indicators of performance. Moreover, the current study sought to explore how individual differences in day-to-day executive dysfunction (as reported by parents) relate to children's subjective experiences and reports in this context. In line with past studies with children in middle childhood (Keulers & Jonkman, 2019; Ye et al., 2014; Zhang et al., 2015), it was hypothesized that children would report being on-task more frequently than mind wandering (H1), and that parental reports of executive dysfunction in daily life would predict a higher frequency of mind wandering (H2). With respect to the validity of children's reports of mind wandering, in line with Seli and associates' (2013) work with adults, it was predicted that children would be less synchronous (H3a) and more variable (H3b) in their keypresses leading up to reports of mind wandering than reports of being on-task. Further, with respect to executive dysfunction, it was predicted that parental reports of greater executive dysfunction in daily life would predict less synchrony (H4a) and more rhythmic variability (H4b) in children's behavioral performance in the MRT.

Methods

Participants

Eighty-six typically-developing children between the ages of seven and nine participated with their parents as part of a larger study of temperament, cognition, and social development. Participants were recruited through community events, social media (e.g., Facebook, Kijiji) and by letters distributed to local schools. Five participants elected not to complete the MRT in its entirety and thus were excluded from analyses. The final sample consisted of 81 children ranging in age from 7.00 to 8.92 years (M_{age} = 7.64, SD = 0.63, 58.0% female). Ethnic demographics reflected those of the surrounding community (75.3% Caucasian, 1.2% Aboriginal, 3.7% East Asian, 1.2% Latin American, 1.2 % South Asian/West Asian/Arab, and 17.3 % mixed race/other) and parent education levels were varied (maternal/paternal education: 0%/1.2% less than high school, 4.9%/2.5% high school, 4.9%/6.2% some university/college, 8.6%/ 19.8% 2-year college, 38.3%/32.5% 4-year university, 43.2%/37.0% advanced/professional degree, 0%/1.2% not reported.)

Materials and Procedure

Participants completed a battery of computerized tasks and questionnaires as part of their visit to the lab. The order in which tasks were administered was constant, with the first block of the MRT being the first cognitive task completed. Measures of interest for the current study are described below. Other tasks completed in the visit did not assess constructs directly related to the current study (e.g., mind wandering, EF).

Behavior Regulation Index of Executive Function (BRIEF). The BRIEF (Gioia et al., 2002) is an 86-item parent-report measure assessing the frequency with which children experience difficulties relating to executive functioning in day-to-day life. Items include “Makes careless errors”, “Thinks too much about the same topic”, and “Becomes upset too easily”, to which parents could respond with “Never”, “Sometimes”, or “Often” (scored as 1, 2, and 3, respectively). Using the factor structure identified by Gioia and associates (2002), two broadband scores of interest were computed: the *Behavior Regulation Index (BRI)*, assessing children’s difficulties with inhibition, attention shifting, and emotional control and the *Metacognition Index*

(MI), assessing children's difficulties with planning, organization, monitoring, and working memory. Higher values indicate greater *difficulties* with EF in each domain. Consistent with Gioia and associates (2002), the Behavior Regulation Index and Metacognition Index were correlated (see Table 1), and the internal consistencies of items in each scale were high (BRI, α = .93; MI, α = .96). For the sake of clear interpretation, Behavior Regulation Index and Metacognition Index scores are hereafter referred to as 'Behavioral Dysregulation' and 'Metacognitive Difficulties', respectively.

Metronome Response Task (MRT). The MRT (Seli et al., 2013) was designed and presented using E-Prime 3.0 (Psychology Software Tools, Pittsburgh, PA) on a 50.8x28.6 cm screen HP monitor displayed at 1920x1080 resolution. As an introduction to the task, participants completed a block of 10 practice trials. Each trial consisted of 650 ms of silence, followed by a 500 Hz metronome tone lasting 100ms, followed by another 550 ms of silence (for a total 1300 ms per trial). Tones were presented at a constant rhythm, and participants were instructed to press the spacebar synchronously with each tone.

Following practice trials, participants were introduced to the concept of mind wandering. To ensure children did not perceive reporting instances of mind wandering as shameful or punishable, the experimenter informed participants that mind wandering was a universal human experience, that the experimenter himself mind wandered from time to time, and children themselves were asked whether they mind wandered in their own lives (see Appendix for the full script). After indicating they understood, participants were informed that periodically throughout the task, the series of tones would be interrupted by a prompt that read "When this screen popped up, were you focused on the beep, or were you mind wandering?". Participants were informed to respond via keypress, pressing 1 if they were on-task at the time of the prompt or 0 if they were mind wandering.

To maximize the number of thought probes presented, each participant completed two blocks of the MRT, each approximately 10 to 12 minutes in length. Each block consisted of 300 trials (tones) with 10 thoughts probes occurring pseudo-randomly in each block for a total of 20 thought probes per participant. After responding to each probe, the presentation of tones would resume following a 3-2-1 countdown. The number of trials presented between thought probes varied between 5 and 55, with an average 25 trials between consecutive probes. Between the two blocks of the MRT, participants completed another computerized task examining children's reading and encoding of information in a simulated social context as part of the broader study. This task took between 15 and 20 minutes to complete. There were no significant differences in reports of mind wandering or behavioral performance between the two blocks and thus both blocks were collapsed in all subsequent analyses (see the Open Science Framework project associated with this study: https://osf.io/frjva/?view_only=a5d65457af904019a2294788497ce7de),

Additionally, at the midpoint and immediately after each block, children were given the opportunity to share the contents of their mind wandering with the experimenter for exploratory purposes. At these time-points, the experimenter asked each participant "Were you mind wandering at all in the last few minutes? What were you mind wandering about?", with no follow-up questions regarding the frequency or content of their thoughts. Responding to this task took no more than one minute. Early in data collection, the utility of these free-response opportunities was drawn into question; many children offered nondescript or indifferent responses, while others offered evidently confabulatory responses. As a result, these free responses were not considered further and do not bear on the data presented in the current study. There were no differences in reports of mind wandering or behavioral performance between the first and second halves of each block (see Supplementary Materials).

Two behavioral indices were generated from participants' keypress response time data: 1) Keypress-Tone Asynchrony, and 2) Response Time Standard Deviation (RTSD). For the 5 tones preceding each thought probe, the absolute value of the difference between the timing of the tone and the timing of the participants' keypresses was averaged. The resulting score (Keypress-Tone Asynchrony) represents how synchronously participants were able to time their keypresses with the presentation of the tones, with greater scores indicating less synchronous keypresses. Further, in line with the measures used in Seli and associates (2013), the standard deviation of the 5 keypresses prior to each thought probe was calculated. The resulting score (Response Time Standard Deviation; RTSD) represents the variability in participants' keypress behavior prior to each thought probe. While derived from the same keypress data and thus likely to be related, RTSD is distinct from Keypress-Tone Asynchrony insofar as a participant could be relatively out of sync with the tone while exhibiting little variability (e.g., being *consistently* early by 200ms over the 5 preceding trials, resulting in a relatively high Keypress-tone Asynchrony score but a low RTSD score). Visual representations of each index and their hypothesized relations to mind wandering are presented in Figure 11.

Analytic Strategy

To address hypotheses H1 and H2, a paired-samples *t*-test and independent linear regressions were conducted, respectively. Given the two-level structure of the data wherein repeated assessments of probe responses and behavior during the MRT (level-1) were nested within participants (level-2), multilevel modeling was considered the appropriate analytic

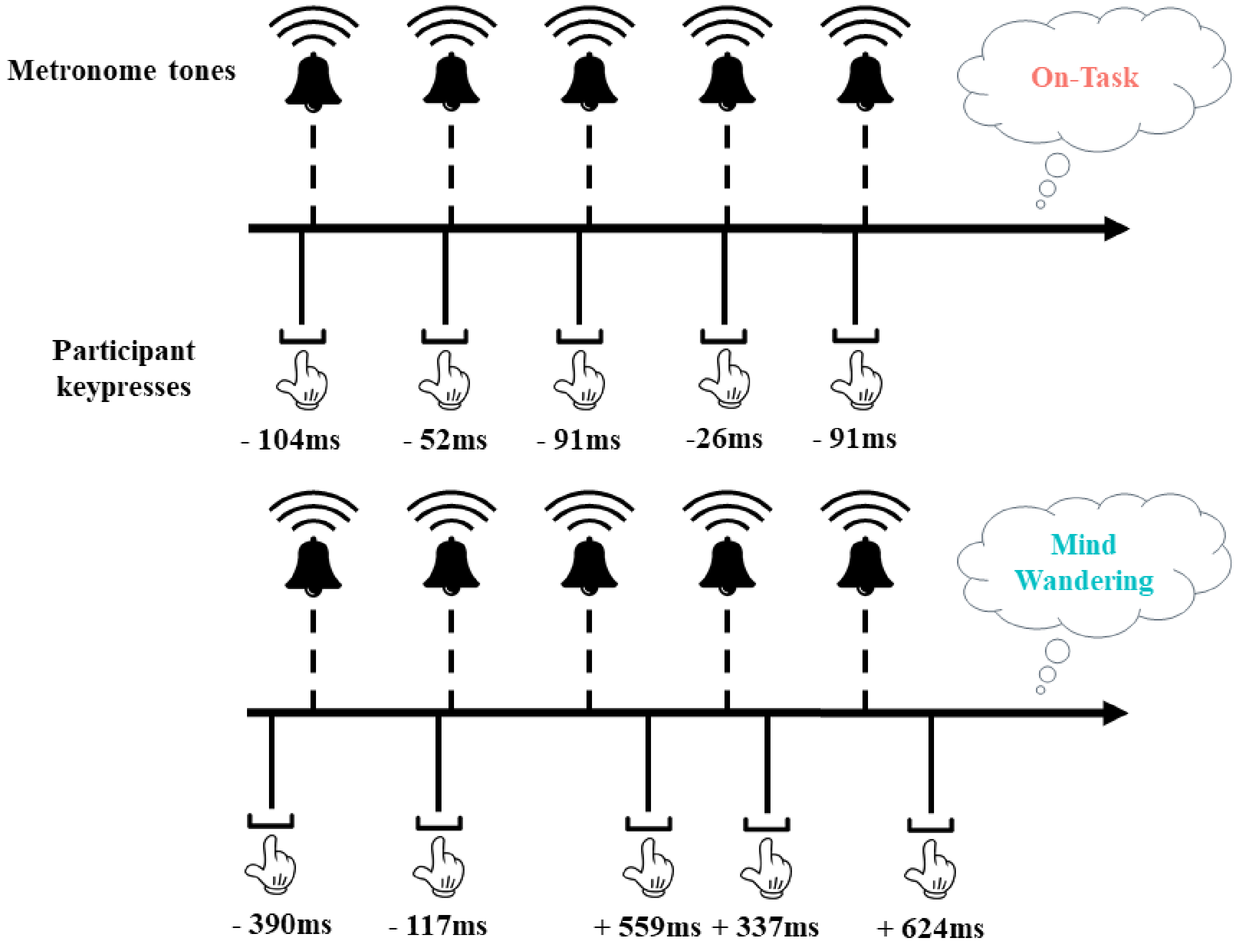

Figure 11. The hypothesized pattern of keypress behavior prior to on-task (top) and mind wandering (bottom) reports. Negative values represent instances where the participant initiated a keypress too early (before the tone occurred), and positive values represent instances where the participant was late (after the tone occurred). Preceding reports of mind wandering, participants' keypresses are hypothesized to be less synchronous with metronome tones (greater distance between solid keypress lines and dashed tone lines) and more variable in timing (inconsistent distances between solid lines and dashed lines) relative to trials preceding reports of being on-task.

approach for investigating H3 and H4 (Nezlek, 2008; Snijders & Bosker, 2012). Multilevel modeling analyses were conducted utilizing a maximum likelihood estimator through IBM SPSS Statistics (Version 26). With more than 50 level-2 units in all analyses, the resulting models are thought to be adequately powered to estimate unbiased regression coefficients, standard errors, and variance components (Maas & Hox, 2005; Paccagnella, 2011). Before carrying out analyses, level-2 predictors (i.e., BRIEF scores and age) were rescaled into *z*-scores relative to the rest of the sample (Heck, Thomas, & Tabata, 2014; Snijders & Bosker, 2012). Additionally, Enders and Tofighi's (2007) recommendations were applied to level-1 binary predictors. Specifically, probe response was dummy coded (Mind wandering = 0 and On-task =1) and entered uncentered into models.

We followed Hox's (2010) bottom-up exploratory approach for our model-building strategy: first a no-intercept model was computed, then level-1 predictors (i.e., Probe Response) were added, and lastly, level-2 predictors (i.e., Metacognitive Difficulties and Behavioral Dysregulation) were added. In each model iteration, the decision to retain fixed and random effects was determined using likelihood-ratio tests (Peugh, 2009; Snijders & Bosker, 2012). When comparing successive models, a statistically significant likelihood-ratio test suggests that the newer model with added predictors better fits the data than earlier iterations. Models that significantly improved model fit are presented below (for a detailed overview of all models, see the Supplementary Materials).

Results

Deidentified data are accessible through the Open Science Framework (https://osf.io/frjva/?view_only=a5d65457af904019a2294788497ce7de).

Descriptive Statistics

Correlations between age, BRIEF scores, and MRT indices are presented in Table 5, and descriptive statistics for MRT indices grouped by probe response are presented in Table 6. The average number of mind wandering reports per participant was 4.86 times out of 20, with 15.14 reports of being on-task. Mean response rates notwithstanding, individuals varied greatly in the

Table 5. Between-participant correlations among age, BRIEF scores, and MRT indices.

	1	2	3	4	5	6
1. Age (years)	-					
2. BRIEF Metacognitive Difficulties	.006	-	**.701****	**-.010**	**.127****	**.103****
3. BRIEF Behavioral Dysregulation	.114	.699***	-	**-.120****	**.102****	**.106**
4. Reports of Mind Wandering	.047	.044	.251*	-	**-.094****	**-.094****
5. Keypress-Tone Asynchrony	-.287**	.231*	.159	.117	-	**.582****
6. RTSD	-.309**	.221*	.197	.176	.758***	-

Note. N = 81. BRIEF, Behavior Regulation Index of Executive Function; RTSD, response time standard deviation. Bolded values above the diagonal represent partial correlations after controlling for age. * p < .05. ** p < .01. *** p < .001.

Table 6. Descriptive statistics for the MRT by probe response. Keypress-Tone Asynchrony and RTSD data are presented as Mean (SD).

	On-Task	Mind Wandering
Total number of reports	1226	394
Percentage of total reports	75.7%	24.3%
Mean number of responses (out of 20)	15.14 (4.30)	4.86 (4.30)
Keypress-Tone Asynchrony (ms)	151.92 (96.63)	173.44 (105.03)
RTSD (variance)	129.44 (90.96)	152.12 (103.67)

frequency of their probe responses. The total number of mind wandering reports per participant ranged from 0 (no reports of mind wandering; n = 13) to 20 (exclusively reporting mind wandering; n = 1). Figure 12 depicts the frequency of reports of mind wandering across the sample.

Prior to analysis, all variables were screened for normality, outliers, and missing values. All study variables demonstrated acceptable normality based on Kline (1998) criterion (i.e., absolute skew values < 3; absolute kurtosis values <10). Probes for which participants failed to initiate a keypress on more than one of the five preceding tones were excluded. Following this

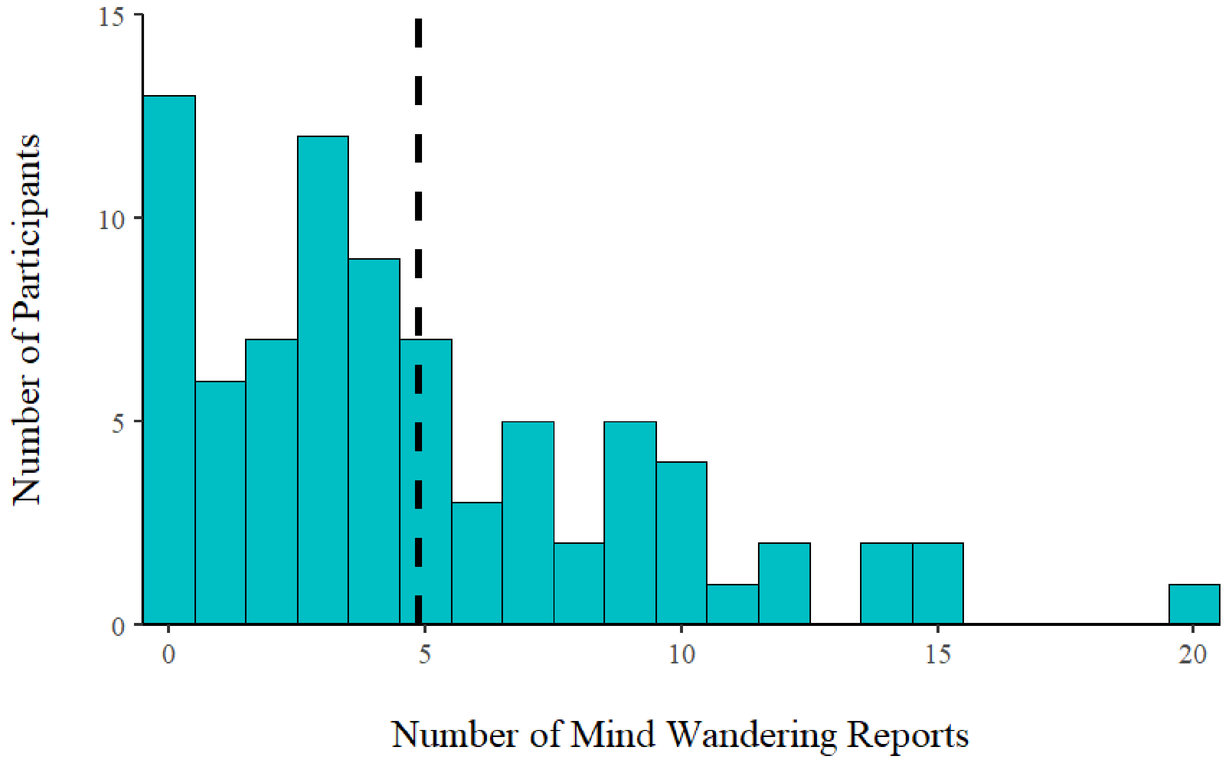

Figure 12. Histogram presenting the frequency of mind wandering rates across the sample. The x-axis presents the number thought probes (out of 20) to which participants indicated they were mind wandering, and the y-axis presents the number of participants reporting that rate of mind wandering. The dashed line presents the mean number of mind wandering reports for the sample.

criterion, 62 probes were excluded (34 On-Task, 28 Mind Wandering), resulting in an adjusted sample of 1558 data points at the within-subjects level (Level 1) distributed across 81 participants at the between-subjects level (Level 2). Further, to limit the influence of extreme scores without removing them outright, scores greater than 3SD above the respective sample means for Keypress-Tone Asynchrony and RTSD were winsorized (Tabachnik & Fidell, 2007), resulting in 23 Keypress-Tone Asynchrony (15 On-Task, 8 Mind Wandering) and 22 RTSD (16 On-Task, 6 Mind Wandering) being replaced. Figures 13 and 14 present the distributions of Keypress-Tone Asynchrony and RTSD data (respectively) grouped by Probe Response. Keypress-Tone Asynchrony and RTSD were correlated, $r(1476) = .495$, $p < .001$.

Frequency of Mind Wandering and Relations to Executive Dysfunction

In line with H1, children reported being on-task more frequently than mind wandering, $t(80) = 10.74$, $p < .001$, $d = 1.20$. In line with H2, as Behavioral Dysregulation increased by one standard deviation, participants were predicted to report 1.09 more instances of mind wandering, $b = 1.04$, $SE = 0.45$, $t(79) = 2.30$, $p = .024$, 95% CI [0.14, 1.94], accounting for 6.30% of the variance in mind wandering frequency, $F(1, 79) = 5.29$, $p = .024$. By contrast, Metacognitive Difficulties did not significantly predict mind wandering frequency, $F(1, 79) = 0.16$, $p = .695$.

Behavioral Data

Multilevel models tested whether children's Probe Responses (H3a, H3b) and Metacognitive Difficulties and Behavioral Dysregulation (H4a, H4b) were associated with their behavioral performance on the MRT, as indexed by Keypress-Tone Asynchrony and RTSD. Given the significant correlations between age and both behavioral indices (see Table 1), Age was added as a covariate to all analyses. Results for Keypress-Tone Asynchrony are presented and RTSD are presented in Table 3 and Table 4, respectively.

Keypress-Tone Asynchrony. An intercept-only model revealed that the intraclass correlation (ICC) for Keypress-Tone Asynchrony was 0.32, indicating that 32% of the total variation in Keypress-Tone Asynchrony occurred at the between-persons level. To test hypothesis H3a, Probe Response was entered as a level-1 fixed effect and Age was entered as a level-2 covariate with a random intercept (see Model 1 in Table 3). Likelihood ratio tests

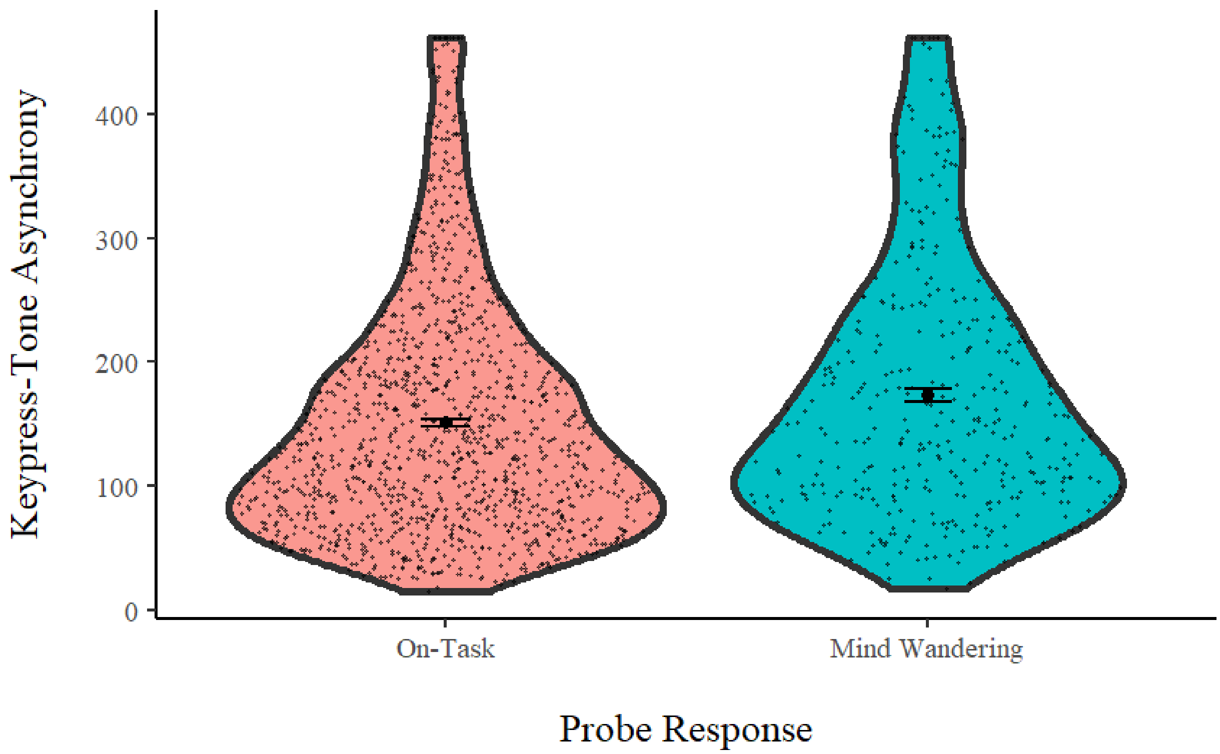

Figure 13. Full distribution of keypress–tone asynchrony data grouped by probe response (on-task vs. mind wandering). Keypress–tone asynchrony is presented on the y-axis, with greater scores indicating less synchrony between keypresses and tones preceding each probe. Each dot represents an individual data point. The means and standard errors for on-task and mind wandering are indicated by the large black dots and error bars. As in a histogram, the width of the shaded region (‘‘violin”) reflects the number of data points falling at that point on the y-axis

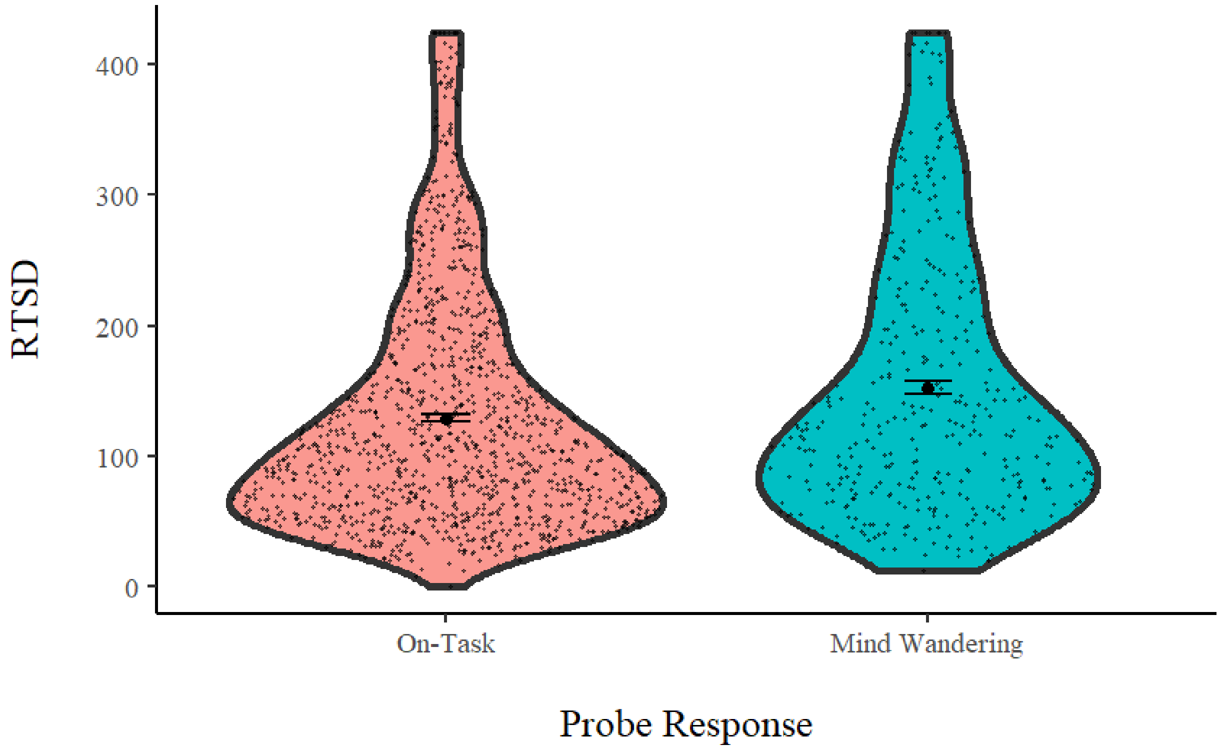

Figure 14. Full distribution of response time standard deviation (RTSD) data grouped by probe response (on-task vs. mind wandering). RTSD is presented on the y-axis, with greater scores indicating more variability in keypresses preceding each probe. Each dot represents an individual data point. The means and standard errors for on-task and mind wandering are indicated by the large black dots and error bars. As in a histogram, the width of the shaded region (‘‘violin”) reflects the number of data points falling at that point on the y-axis.

revealed the iterative addition of Probe Response, $\chi 2(1) = 12.99$, $p < .001$ and Age, $\chi 2(1) = 7.14$, $p = .008$, significantly improved the model. Specifically, participants' keypresses preceding reports of mind wandering were more out of sync (by approximately 20.06 ms) with their corresponding tones than their keypresses preceding reports of being on-task. Results also showed that the keypresses of participants who were one standard deviation (0.63 years) younger than the mean age of the sample (i.e., $M = 7.64$) were on average 16.94 ms more out of sync with corresponding metronome tone than the keypresses of participants at the mean age of the sample (regardless of probe response).

To test hypothesis H4a, Metacognitive Difficulties and Behavioral Dysregulation were added to Model 2 (see Model 2 in Table 3). Likelihood ratio tests demonstrated that Metacognitive Difficulties, $\chi^2(1) = 4.92$, $p = .026$), but not Behavioral Dysregulation, $\chi^2(1) = 2.80$, $p = .095$, significantly improved the model. Thus, Behavioral Dysregulation was trimmed from the final model. Results indicated that the keypresses of participants who had greater metacognitive difficulties (i.e., more difficulties by 1 standard deviation above the sample mean) were on average 13.72 ms more out of sync with the corresponding metronome tone than the keypresses of participants with average metacognitive difficulties (regardless of probe response and age).

RTSD. An intercept-only model revealed that the ICC for in RTSD was 0.18, indicating that 18% of the total variation in RTSD occurred at the between-persons level. To test hypothesis H3b, Probe Response was entered as a level-1 fixed effect and Age was entered as a level-2 covariate with a random-intercept (see Model 1 in Table 4). Likelihood ratio tests revealed that the iterative addition of Probe Response, $\chi^2(1) = 11.91$, $p < .001$, and Age, $\chi^2(1) = 8.48$, $p = .004$, significantly improved the model. Specifically, the rhythm of participants' keypresses preceding reports of mind wandering was more variable (i.e., higher RTSD by approximately 19.75 ms) than that preceding reports of being on-task. Also, the keypresses of participants who were one standard deviation (0.63 years) younger than the mean age of the sample were on average 13.88 ms more variable than the keypresses of participants at the mean age of the sample (regardless of probe response).

To test hypothesis H4a, Metacognitive Difficulties and Behavioral Dysregulation were separately added to Model 2 (see Model 3a and Model 3b in Table 4, respectively). Likelihood ratio tests revealed that the addition of Metacognitive Difficulties to Model 2 significantly improved model fit, $\chi^2(1) = 4.60$, $p = .032$. Specifically, the keypresses of participants who had greater metacognitive difficulties (1 SD above the sample mean) were on average 9.93 ms more variable than the keypresses of participants with average metacognitive difficulties (regardless of probe response and age). In a separate model, likelihood ratio tests demonstrated that the addition of Behavioral Dysregulation to Model 2 significantly improved model fit, $\chi^2(1) = 4.17$, $p = .041$. Results showed that the keypresses of participants who had greater Behavioral Dysregulation (1 SD above the sample mean) were on average 9.56 ms more variable than the keypresses of participants with average Behavioral Dysregulation (regardless of probe response and age). When both Metacognitive Difficulties and Behavioural Dysregulation were simultaneously added to Model 2, likelihood ratio tests suggested that the model did not significantly improve, $\chi^2(2) = 5.19$, $p = .075$.

Discussion

The current study builds on prior work by examining the frequency and validity of children's reports of mind wandering in a minimalistic task with low explicit performance demands and no obvious external indicators of performance, mirroring the conditions in which mind wandering is subject to occur in the real world. Additionally, the current study examined the relations between two indices of executive dysfunction in daily life, children's self-reported mind wandering, and task performance. Results partially supported our hypotheses, as children reported being on-task more frequently than mind wandering (H1) and children higher in Behavioural Dysregulation, but not Metacognitive Difficulties, reported more frequent mind wandering (H2). Notably, children were less synchronous (H3a) and more variable (H3b) in their key presses leading up to reports of mind wandering than reports of being on-task, supporting the validity of their self-reports. Additionally, children higher in Metacognitive Difficulties were less synchronous (H4a) during the MRT, while children high in Behavioural Dysregulation were both less synchronous (H4a) and more variable (H4b).

Frequency and Individual Differences in Reports of Mind Wandering

Across the sample, children reported mind wandering in approximately a quarter (24.3%) of all probes, with individual response rates ranging from exclusively mind wandering (20/20 probes) to no mind wandering whatsoever (0/20 probes). The overall rate of mind wandering found in the current study closely approximated those reported by Keulers and Jonkman (2019; 25.3% in a classroom listening task; 20.4% across three EF tasks), while being somewhat lower than those reported by Ye and associates (2014; 37-39%) and Zhang and associates (2015; 33%), despite studying similar age ranges. This variability across studies, as well the variance within samples, underscores the importance of considering what individual, group, or task-specific factors influence children's reports of mind wandering.

With respect to individual differences, greater Behavioral Dysregulation, but not Metacognitive Difficulties, predicted higher rates of self-reported mind wandering, providing partial support for H2. The significant relation between mind wandering frequency and Behavioral Dysregulation is consistent with findings reported by Keulers and Jonkman (2019), wherein lower levels of inhibition and (to an extent) attention shifting were related to a higher rate of mind wandering. Moreover, Keulers and Jonkman found mind wandering frequency to be unrelated to working memory, one of the core components of the Metacognitive Difficulties index in the current study. While effect sizes were modest, these convergent findings suggest that cognitive flexibility and control may play a specific and important role in the manifestation of mind wandering in early childhood. This also suggests mind wandering might be a mechanism linking behavioral dysregulation with important academic, social, and developmental outcomes (e.g., Langberg et al., 2013; Mahone et al., 2002; Toplak et al. 2008).

Validity of Children's Mind Wandering Reports

With respect to the validity of children's reports of mind wandering, children were consistently less synchronous and more variable in their keypresses leading up to reports of mind wandering than reports of being on-task. This was particularly true for children higher in Metacognitive Difficulties (difficulties with planning, organization, monitoring, and working memory in everyday life), and to a lesser extent children higher in Behavioral Dysregulation (difficulty with inhibition, attention shifting, and emotional control in everyday life). This overall validity of children's reports is consistent with results from past MRT studies with adults (Anderson et al., 2020; Seli et al., 2013) and in line with recent studies examining behavioral correlates of children's responses to experience-sampling probes (e.g., Keulers & Jonkman, 2019; Zhang et al., 2015), providing support for the validity of children's insight into their experience with mind wandering.

Notably, the average age of children in the current sample was only 7.64 years, making the current sample among the youngest in past mind wandering in children (alongside McCormack et al., 2019). Consistent with past work assessing children's performance on rhythmic tasks (e.g., McAuley et al., 2006; Repp & Sue, 2013; Smoll, 1974), children's ability to initiate keypresses in synchrony with metronome tones improved with age. Importantly, however, probe response accounted for unique variance over and above any influence of age, suggesting that as early as middle childhood, children's introspective knowledge of occurrent, internal experiences can be the subject of meaningful study, opening up potential avenues of research at earlier ages than once thought.

The MRT requires sustained attention to the metronome but does not explicitly require inhibitory control or cognitive flexibility, which may explain the more consistent relations between MRT performance and Metacognitive Difficulties as compared to Behavioral Dysregulation. At the same time, Behavioral Dysregulation, but not Metacognitive Difficulties, predicted higher rates of self-reported mind wandering. One interpretation of this finding is that while children higher in Metacognitive Difficulties *also* mind wander at an elevated rate, they lack the metacognitive awareness to report on such experiences. Children's metacognitive insight into their mental processes may prove to be an important predictor of other developmental outcomes. Van den Driessche and associates (2017) found that both children with ADHD and adults with subclinical ADHD reported significantly more 'mind blanking' (i.e., instances in which one is unable to report on the contents of one's thoughts) during the SART than did control participants. Similarly, Franklin and associates (2017) found that lower awareness of mind wandering in adults mediated the relation between ADHD symptomatology and the negative effects of mind wandering in daily life. While the current study does not have the statistically power to conduct a mediation analysis, future work should assess whether indices of children's metacognitive skills mediate the association between self-reported mind wandering and performance on the MRT.

Interestingly, the relations between children's mind wandering and BRIEF scores were broadly consistent with past work examining mind wandering in relation to behavioral measures of executive function, (Keulers & Jonkman, 2019), despite past work suggesting that parent-reported BRIEF scores do not necessarily correlate strongly with behavioral measures of executive functioning and may in fact assess distinct constructs (e.g., Anderson et al. 2002; Toplak et al., 2013). The optimal strategy for future mind wandering research with children may be to examine both parent reports and behavioral indices of executive function in tandem. That is, while behavioral measures can offer a high degree of fidelity in the assessment of subtle internal processes such as momentary changes in self-monitoring, parent reports can provide a ‘big-picture’ perspective on a child’s broader behavioral development that would not be similarly captured in a cognitive task. Together, examining behavioral measures of children’s monitoring and metacognitive capacities, in conjunction with parent-report measures assessing children’s broader behavioral development, may prove fruitful for future studies seeking to parse the role of these specific regulatory processes in children’s mind wandering tasks.

Limitations and Future Directions

It is important to note that effect sizes for probe response as a predictor of MRT behavioral variables were modest. Given the subtlety of the behavioral measures derived from the MRT (small variations in the timing of response behavior), a certain level of unexplained variability is to be expected. Beyond this inherent noise, additional variability likely arose due to developmental limitations in children’s understanding or insight into the nature of mind wandering. It may be that in middle childhood, while able to report on particularly deep or vivid instances of mind wandering, children are still limited in their insight into smaller deviations of their attention (enough to alter behaviour without entering conscious awareness). Definitional issues may also have contributed to some of the unexplained variability in children’s responses. The introductory prompt defining mind wandering in the current study, modeled after definitions used in past studies (e.g., Thomson et al., 2014), was intentionally broad and devoid of specific examples of content to avoid leading children to believe that only certain kinds of mental events ‘count’ as mind wandering. However, a more elaborative introduction to the concept of mind wandering (careful to avoid priming particular responses) may facilitate children's reflections in future studies.

Similarly, thought probes in the current study were dichotomous in nature, contrasting being on-task with mind wandering), as *any* internal experience drawing children's attention away from the task was of interest. However, given their burgeoning metacognitive capacities, children may benefit from more guided or incisive probes. These could include Likert-style measures of *depth* or *clarity* of mind wandering (e.g., Christoff et al., 2009; , McCormack et al., 2019), questions regarding the *intentionality* of mind wandering (e.g., Vannucci & Chiorri, 2008), or evaluations of the *content* of their thoughts. Content-oriented probes might pose questions regarding different forms of mind wandering (e.g., future- vs. past-oriented thoughts, Ye et al., 2014; positively vs. negatively valenced thoughts, Smallwood et al., 2009), and/or potential alternatives to mind wandering (e.g., "mind blanking", Van den Driessche et al., 2017; external distractions; Stawarczyk et al., 2014). With these considerations in mind, the response variability predicted by probe response in the current study may simply be the 'tip of the iceberg'. Assessing the content of children's mind wandering may yield important insights into the factors influencing children's metacognitive awareness, although this may pose unique methodological challenges. As an exploratory consideration in the current study, children were given the opportunity to share the contents of their mind wandering freely at the midpoint and end of each block of the task. Ultimately this proved ineffective as children's free-responses were generally vague, nondescript, and/or confabulatory, and thus were not deemed viable for coding. Recollecting the contents of their thoughts may have been made difficult by the time elapsed between thought probes and the free-response opportunities as well as the open-ended nature of the questioning. A dichotomous probe was chosen for the current study as our hypotheses did not extend to specific forms of mind wandering; indeed, *any* internal experience drawing children's attention away from the task was of interest. Future studies should explicitly examine how varying task instructions and demands impact the frequency and content of children's mind wandering (as well as their metacognitive awareness thereof).

Conclusion

In sum, through the use of a task previously unexplored in past developmental research, the current study contributes to our understanding of the contexts and factors influencing children's subjective experience of mind wandering. Our findings build upon important developmental work in the area (e.g., Keulers & Jonkman, 2019; Zhang et al., 2015), and highlight important future directions for the study of mind wandering in children. Although the present findings need to be replicated with a larger and more diverse sample, we provide empirical evidence that children's self-reports of attentional states can be reliably studied as early as age 7. Through the use of such methods, our study of children's mind wandering can be expanded in both basic and applied settings, enriching our understanding of children's subjective experiences in both the laboratory and the real world.

Chapter Five: General Discussion

Summary of findings and overview of discussion

The overarching goal of my research is to better understand the mechanisms underlying the relations between the executive functions and the social outcomes of shy and behaviorally inhibited children. To this end, my collaborators and I proposed a theoretical account explaining how variability in shy children's self-regulation may differentially impact the quality of their interactions with peers and accordingly bear significant downstream effects on their experience of social anxiety (Fox et al., 2021; Henderson & Wilson, 2017). With this account as an organizing framework, the studies described in this dissertation advance our understanding of how the interplay of temperamental reactivity and attention regulation underlie children's social development in nuanced ways. Through these studies, I developed new empirical approaches for studying children's attention and behaviour across social and non-social conditions, laying the groundwork for both basic and applied research examining children's attentional flexibility, internal experiences, and broader patterns of behaviour in social contexts.

Chapter 2 investigated how children's performance in an attention-shifting task is influenced by the expectation that their performance would be evaluated by a peer, and how this effect varies as a function of shyness. I found as shyness increased, children slowed their responding more in the social monitoring condition relative to baseline. Critically, this slowing did not result in more accurate responding as performance was high across the board, bringing into question whether inefficiency and/or rigidity in children's attention allocation in social contexts may contribute to their difficulties engaging with peers.

Chapter 3 focused on the role of turn-taking response time (RT) during children's conversations with a new acquaintance as an index of social engagement and a source of meaningful individual differences in social behaviour. Two new approaches to the coding of children's communications were developed, centering on the content of their communications as well as their timing in the flow of turn-taking conversation. Faster turn-taking RTs were associated with greater social engagement as indexed by third party observers, both in children themselves and marginally in children's dyadic partners, supporting the use of turn-taking RT as an objective index of engagement in naturalistic dyadic interactions. Moreover, children's self-reported shyness was unrelated to their own turn-taking RTs but inversely related to their partner's RTs, suggesting that even previously unfamiliar peers pick up on something in how shy children behave or communicate that leads them to shorten the latency of their communications (or in the case of low shy children, leads them to slow things down). This finding, only apparent upon considering subtle differences in communicative behaviour, offers novel insights into children's ability to reflexively modulate their behaviour to accommodate the social characteristics of their peers.

Chapter 4 examined the validity of children's reports of mind-wandering while completing a simple behavioural task (pressing a button in sync with a metronome), and further whether children's self-reported mind-wandering and task performance were related to difficulties with self-regulation (as reported by parents). We found children's keypress behaviour was more variable in the trials leading up to self-reports of mind wandering relative to self-reports of being on-task, supporting the validity of children's reports. With regard to self-regulation, children rated as having more difficulties with behavioural regulation (inhibition, attention shifting) reported more frequent mind wandering, while children exhibiting greater difficulties with metacognitive tasks (planning, self-monitoring) were more variable in their task performance overall, providing further support for the validity of the task. This study is among the first to examine children's introspective experience of mind wandering. By taking steps to validate children's self-reports, this work opens the door for several lines of basic and applied research exploring children's inward-focused attention (historically a very difficult construct to operationalize) in a variety of contexts, such as in the classroom or during peer interactions.

Together, these findings highlight that to fully understand what temperamental, contextual, and self-regulatory factors come to bear on children's social development, it is essential to examine children's cognition and behaviour at various focal lengths: one must consider both the moment-to-moment variations in attention that could create rifts in the interaction between two children, as well as the behavioural consequences of these rifts that emerge at the dyadic level over a longer period of time. They also underscore the importance of studying children's cognition and behaviour in social contexts, in which elicited social concerns and self-evaluative thinking may fundamentally change how children engage with the worlds around them.

Throughout the general discussion of my dissertation studies presented below, I aim to broadly contextualize and draw connections between the findings from Chapters 2-4 within our account of how individual differences in attention may relate to children's social development (Fox et al., 2021; Henderson & Wilson, 2017). I highlight how my findings and the empirical methodologies I have developed through these studies can guide future research and test additional predictions of our account, as well as exploring how our framework might be extended to account for the social behaviour and outcomes of temperamentally exuberant children. I go on to discuss an important recurring theme of my research: the importance of examining children's attention and behaviour in *social* contexts to fully capture the ramifications of individual differences in temperament on children's ability to meet their immediate goals and form connections with others. I conclude by discussing the need for future studies to incorporate empirical measures of children's internal experiences to paint a fuller picture of how inward-focused attention may impact children's day-to-day interpersonal interactions and social functioning.

Exploring the role of flexibility in social contexts: Revisiting our theoretical model

Our account contends that individual differences in children's temperamental reactivity predict the extent to which their attention is captured and absorbed by salient social events in their surroundings. An event which may elicit only a perfunctory glance or mental note from an exuberant child may become instantly engrossing for a shyer child, sucking their attention away from other immediate social concerns. Our account further proposes individual differences in the attentional self-regulation strategies shy children enact play a central role in their ability to effectively rebound from such attention-orienting events: while children with proficient attention-shifting skills can quickly redirect their attention back to their social goals, children relying on inhibitory self-regulation may continue to allocate their attention to the salient event at the cost of keeping up with emerging developments in their social interaction. This lingering allocation of attention can be externally focused (e.g., hypervigilantly monitoring of the source of the event for additional signals) or internally focused (e.g., ruminating on the cause or meaning of the event, or worriedly anticipating a future one); both are compatible with our account.

The existence of our account serves to move the field forward in several ways. First, it synthesizes a diverse array of findings regarding shyness/behavioural inhibition (BI), self-regulation, attention, and social behaviour into a unified theoretical model. Second, it proposes a parsimonious framework for explaining counterintuitive or seemingly paradoxical findings (e.g., enhanced response inhibition negatively impacting children's social behaviour, as in White et al., 2012). And third, it makes clear predictions about how components of temperament and self-regulation should interact to predict children's social outcomes, both in the short term (e.g., the success of a single interaction between new acquaintances) and the long term (e.g., children's developmental trajectories with regard to social anxiety).

These contributions of our account notwithstanding, what is still missing from both our account and from the field at large are means of *empirically testing* the relations between temperament, self-regulation, and social outcomes as they occur in real-world social contexts. Recall the example of Tyler and Colin playing with blocks in Chapter 1. While the vector diagrams presented as part of our account (Figs. 1-3) provide a rich and intuitive means of depicting Tyler's attention as it is pulled away from his interaction with Colin, there remains to be a clear way of operationalizing how we might empirically study this shift in attention. To this end, the three studies presented in this dissertation all aim to inform this account in different ways, whether by testing its underlying assumptions (Chapter 2 and 3) or developing new methodological approaches for quantifying these processes (Chapters 2, 3, and 4).

The other end of the spectrum: Accounting for temperamental exuberance

The findings from my dissertation studies also suggest it may be worthwhile to expand the scope of our account to consider children at the other end of the spectrum of social reticence. That is, while our account focuses specifically on the social behaviour of shy and BI children, our conceptualization of how attention to salient social events may predict the outcomes of an interaction may also be applicable to the social behaviour of *exuberant* children. Temperamental exuberance is characterized by frequent and intense expressions of positive emotions, high levels of sociability, and higher levels of impulsivity (Degnan et al., 2011; Putnam & Stifter, 2005).

Notably, in contrast to the internalizing problems to which shy and BI children are predisposed, exuberant children are at increased risk of developing externalizing behaviours (e.g., aggression, hyperactivity; Degnan et al., 2011; Rydell et al., 2003). Attention also plays an important role in the relation between exuberance and externalizing behaviours, with greater attention biases to reward predicting more externalizing problems (Morales et al., 2016; 2020) and attention shifting serving as a protective factor (Lahat et al., 2013; Morales et al., 2016).

Chapter 2 found children at the low end of the shyness distribution were *faster* to respond under social conditions (relative to their own performance in the non-social condition), in stark contrast to the relatively slower response times exhibited by shyer children in the social (vs. non-social)condition. Further, in Chapter 3, as children's shyness increased, their partners' turn-taking RTs increased (i.e., their partner responded more quickly in conversation). Given the goal of informing our theoretical account, it is tempting to interpret this linear relation solely in terms of the social implications of shyness: when interacting with a visibly shy peer, children may increase their RT in reciprocal conversation to compensate for their peer's reticence. However, as shyness is measured continuously rather than contrasting high vs. low shy groups, it is equally important to approach this relation from the opposite direction: when interacting with an outgoing peer, children may be inclined to respond more slowly, allowing their peer to take the reigns of the conversation and move things forward. Notably, while shyness and exuberance theoretically should be inversely related, it is not enough to say exuberance can be fully captured by low scores on a shyness scale; a child who is unfazed by social novelty could simultaneously be relatively low in their gregariousness and tendency toward expressing positive emotions (Putnam & Stifter, 2005; Rothbart et al., 2001). Future studies should seek to assess both social approach and avoidance motivations in tandem (as in Gray's biopsychological theory which differentiates between behavioural activation and inhibitions systems; Gray, 1981) to more comprehensively capture the motivations and resulting behaviours that influence children's social interactions with peers.

Expanding on the predictions of our account, while shy and BI children may instinctively allocate too much attention to salient social events, under certain circumstances, highly exuberant children may not allocate *enough* attention to events outside the scope of their immediate goal. For example, whereas a shy child may read too much into look of frustration or distress expressed by a peer, a highly exuberant child might overlook this expression altogether, failing to recognize important social signals outside their primary goal and potentially opening the door for conflict. Accordingly, inhibition would be an important *protective* factor against externalizing behaviours for exuberant children, enabling them to downregulate their high activity levels and attend to other important aspects of their interaction (e.g., extending a kind word or a social smile to an apprehensive peer). Figure 15 illustrates this prediction using hypothetical data from two children identical in their level of exuberance but varying in their inhibition skills. The low levels of inhibition exhibited by the child in the left panel could result in them being *too* focused on their immediate goal, preventing them from adequately attending to other important aspects of their interaction (e.g., engaging in brief conversational asides with their playmate). In this sense, a singular focus on the primary social task when a moment of pause was warranted could itself put a strain on the relationship between two peers. By contrast, the higher levels of inhibition exhibited by the child in the right panel would allow them to flexibly attend to other aspects of their interaction before returning to their original task.

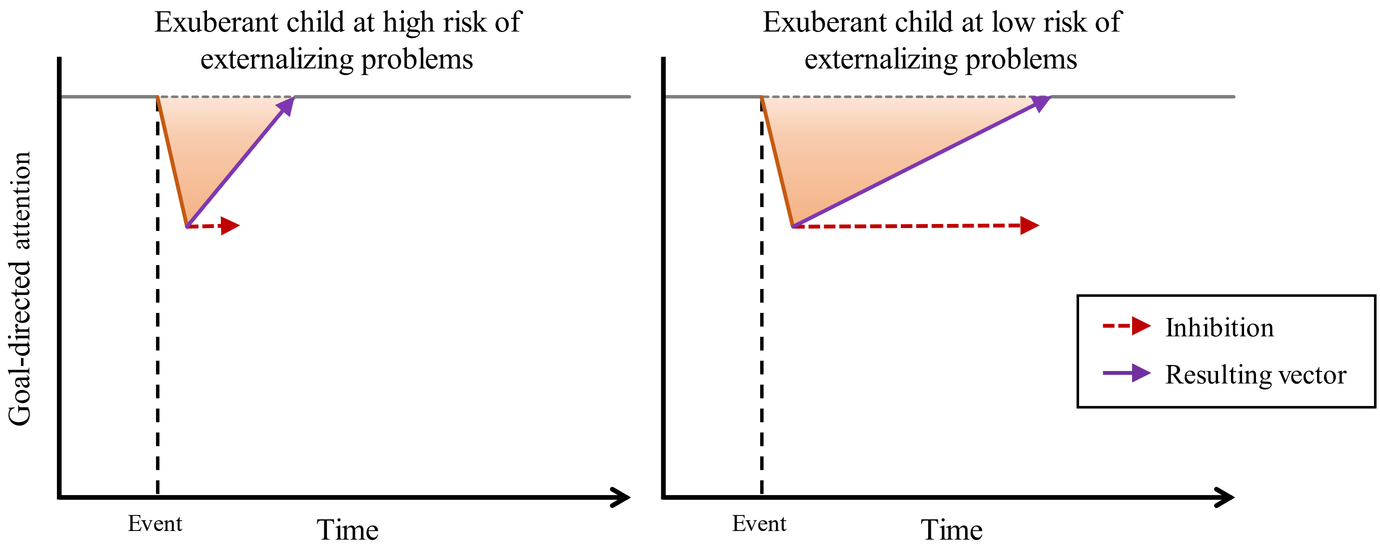

Figure 15. The goal-directed attention of two exuberant children in response to the detection of a salient event in a social context, one with low inhibition (left) and one with high inhibition (right)

In the end, whether predicting the behaviour and outcomes of shy or exuberant children, the ultimate take-away remains the same: to support healthy social development, attentional flexibility is key to navigating a complex social world.

Considering of social context in the study of temperament, cognition, and behaviour

Shyness does not exist in a vacuum; the patterns of behaviour characteristic of shyness are specifically evoked in response to novelty and prospective social evaluation. Critically, engagement and activity levels in familiar contexts may be dramatically different (Calkins et al., 1996; Fox et al., 2001; Frasier-Wood & Saudino, 2017; Lahat et al., 2012). With this in mind, to fully understand how shy children's allocation and regulation of attention predicts their social development, it is not enough to look at standard laboratory measures of attention and independent assessments of social behaviour in parallel. Rather, it is essential to directly compare and contrast how children's attention varies between social and non-social conditions, thereby providing a clearer picture of how they may attend to their surroundings in their day-to-day social lives. Accordingly, Chapter 2 introduces a simple contextual manipulation that can be easily applied to any number of traditional cognitive tasks with children.

Chapter 2 found shyer children were slower to identify the location of a target in a hierarchical figure under social relative to non-social conditions. To draw parallels between this study and the example of Tyler and Colin presented in Chapter 1, attending to the screen and correctly identifying the targets would be the equivalent of Tyler focusing on building the Lego castle; it is the immediate, goal-directed task at hand. Accordingly, the presence of the video camera in the social condition potentiating children's social evaluative concerns corresponds to the presence of Colin working alongside Tyler: a contextual factor whose presence does not directly impact one's performance of the task but nonetheless exerts an influence on the shy child's attention. According to our account, the very presence of Colin as a potential source for evaluation would pull Tyler's attention away from his immediate goals and make him less efficient at completing his task, and this interpretation can be applied to the findings from Chapter 2.

There are two plausible interpretations of this relation between shyness and differences in performance between the two conditions observed in Chapter 2. On the one hand, the social evaluative concerns evoked by the social monitoring manipulation may have been manifest as task-irrelevant intrusive thought, pulling children's attention directly away from the task and thereby interfering with their performance. This interpretation, described in past studies as "cognitive busyness" (Wolfe & Bell, 2014), falls most directly in line with the predictions of our account (Fox et al., 2021; Henderson & Wilson, 2017). However, an alternative interpretation, consistent with the data from Chapter 2, is that shyer children adjusted their internally defined goal states in response to the social manipulation: with concerns about social evaluation at the forefront of their minds, shyer children may have placed greater value on avoiding mistakes than on responding quickly and altered their behaviour in turn. The inability of this study to differentiate between these two possibilities speaks to a broader limitation of the research in the field: when it comes to making sense of how internal experiences such as intrusive thoughts and drifting motivations influence children's cognitions, affect, and behaviour, the vast majority of past studies offer only conjectural accounts of what goes on in a child's mind as they interact with peers. This was a major motivator of the research presented in Chapter 4 and will be revisited in sections below.

Chapter 3 sought to further explore the predictions of our model in an ecologically valid social context. In support of our model, turn-taking RT was found to be positively associated with third-party reports of a child's own social engagement (a composite of openness, social ease, and appropriateness) and marginally associated with their peer's social engagement. These findings are consistent with past adult work highlighting turn-taking RT as a subtle affiliative cue that supports social connection (Roberts et al., 2011; Templeton et al., 2022) and supports a key assumption of our model: fast and flexible engagement with one's social partners is central to high-quality social interaction. The immediate next step for this line research would be to go beyond third-party reports of engagement to explore how turn-taking RT relates to children's own self-reported feelings of connection with their peers. Our model contends shy children may get "stuck in a rut" when their attention is pulled away from the goals shared with their peers in an interaction; the outstanding empirical question concerns whether the social partners of shy children *take note of* such interruptions in the flow of conversation, and how such perturbations impact the extent to which they like and feel connected to their shy peer.

One approach would be to have children act as third-party witnesses of an interaction, manipulating the latency between turns in order to observe its effect on children's reports of social connection or likeability. Children would report on how connected the children in the exchange appear to be (as did one team of coders in Chapter 3 and the adult participants in past studies with adults; Roberts et al., 2011; Templeton et al., 2022). An even more direct approach would have children actively participate in an experimentally manipulated conversation themselves, engaging with an interlocutor (the latency of whose utterances are predetermined) in a chatroom or telephone conversation. In addition to testing core assumptions of our model and allowing for the direct comparison across high- and low-shy children, this approach would rule out any partner effects evoked by an individual that would otherwise need accounting for (such as the negative association between children's shyness and their partner's response times observed in Chapter 3). Moreover, exercising control over the course of the interaction would empower experimenters to prompt children with conversational "curveballs" in the form of jarring social events or abrupt topical pivots, thereby putting children's flexibility to the ultimate test.

Taking things in a more ecologically valid direction, future studies could evaluate individual differences in turn-taking response time occurring naturally in dyadic interactions as predictors of children's own self-reports of connection and likeability (as in Templeton et al., 2022). Following an interaction between two peers, children would provide their perceptions of their peer, as well as perceptions of how they (the children themselves) were perceived by their peers (i.e., metaperceptions; Dockrill et al., in prep; Kenny & DePaolo, 1993). Another approach, incorporating a similar manipulation as in Chapter 2, would be to observe children's turn-taking RT during interactions with a peer while manipulating (across dyads) whether children believe their interaction will be followed by a) a formal social evaluation from their peer or b) a collaborative and/or non-evaluative task. By directly manipulating whether children see their peer as a source of social feedback or allyship, such a study would inform our model by establishing a causal relation between the experience of self-consciousness and the fluidity of children's social engagement.

It is also important to consider how children's turn-taking RT relate to their evaluations of their *own* likeability. Self-consciousness about the presentation of anxiety symptoms is itself a central feature of both shyness and social anxiety (Bögels et al., 1996; Crozier & de Jong, 2013; Leary et al., 1992). Children's perceptions that they are dragging the pace or failing to keep up with the conversation may acutely exacerbate their feelings of social discomfort, resulting in a paralyzing cycle of negative self-evaluation and rigid social behaviour. The coding scheme and analytical approach developed in Chapter 3 relating turn-taking latencies to children's social engagement offer a clear path to addressing such questions.

Notably, the findings presented in this dissertation do not offer unilateral support for the predictions from our model. Contrary to our hypotheses, Chapter 3 found shyness was unrelated to children's own turn-taking RT. Our theoretical account posits that shyer children's attention will be captured to a great extent by salient social events, and as such, one might expect that on average, shy children would take longer to "rebound" from these attention demanding events. It may be that looking at average RT across all conversational turns is too broad an approach; the critical moments where shy children fall out of sync with their peers and strain is placed on their emergent relationship may occur in response to infrequent but impactful events wherein shy children perceive rifts or social judgments to be occurring.

Alternatively, capturing the relation between shyness and turn-taking RT may require considering an important mediator outlined by our account: the extent to which children rely on attention shifting vs. inhibition to response to attention-orienting events (Fox et al., 2021; Henderson & Wilson, 2017). Shyer children with adept attention-shifting skills may be virtually indistinguishable from their more exuberant peers in their ability to keep up with the flow of conversation, segue between topics, etc. By contrast, shyer children for whom inhibition is the predominant means of self-regulation may find themselves struggling to engage in conversation, their inclinations toward inhibition leading them to be slower to respond for fear of social missteps. Future work with sample sizes sufficient to conduct more complex mediation analyses will be able to shed light on the nuance of these relations.

Beyond conjecture: New directions for empirically studying children's internal experiences

Researchers take many approaches to understanding the cognitive and affective processes influencing trajectories of social development. Neurophysiological indices provide nuanced insight into the biological processes underlying children's social information processing, such as orienting to emotional faces (e.g., Bar-Haim et al., 2007), monitoring their own task performance (e.g., McDermott et al., 2009), and receiving peer feedback (e.g., Guyer et al., 2014). The behavioural coding of live social interactions offers rich, ecologically valid descriptive information, highlighting how children of varying temperaments respond in dramatically different ways in response to the same tasks and environment (e.g., Chapter 3; Buss, 2011; Degnan et al., 2014; Rubin et al., 2002). And as discussed above, contrasting task performance across social and non-social conditions highlights the implications of the perceived presence of peers on children's goal-directed behaviour (e.g., Barker et al. 2018; Buzzell et al., 2017; Wilson & Henderson, 2020 [see Chapter 2]).

However, despite the illustrative findings these approaches produce, when tasked with contextualizing these empirical data within an account of what a child *subjectively experiences* in a given moment or context, researchers typically fall back on conjecture. That is, standing on the outside looking in, researchers offer an account of what they believe a child might be thinking or feeling as they exhibit heightened error-related negativity or greater response latencies, but these interpretations go beyond the empirical data, rooted only in researchers' own intuitions. Examples of such conjectural accounts (and their limitations they impose) can be seen throughout the chapters presented in this dissertation. As discussed in Chapter 2, whether changes in children's response time between the social and non-social conditions were the result of increased cognitive loads arising from "cognitive busyness" or due to shifts in children's motivation to make speed-accuracy trade-offs remains unclear. Both explanations are plausible and consistent with the data but involve entirely different accounts of children's internal experiences.

Overcoming this empirical challenge is not simple. Self-report questionnaires of one's experiences in specific contexts, while useful for assessing trait characteristics and offering gross insight into children's subjective experiences, are not linked to specific events that can be experimentally controlled or observed. Retrospective assessments of one's experiences immediately following the completion of a task (such as the Trier Social Stress Task; Buske-Kirschbaum et al., 1997; Lau et al., 2021) offer more specificity, but nonetheless lack the precision to capture momentary changes in children's thoughts, feelings, and motivations in response to specific events.

A novel empirical approach explored in Chapter 4 that would allow researchers to move beyond conjecture and to incorporate the subjective reports of children themselves in the interpretation of social phenomena is through the use of *experience-sampling probes*, periodic self-report cues presented in the midst of a broader task. Experience-sampling probes are an incredibly versatile tool used commonly in adult research and that can be used to address a variety of research questions and supplement other empirical data. They can be presented either at random intervals or systematically following specific events (e.g., critical trials in an experimental task; following specific events in a social interaction). They can also prompt the participant with any number of questions from simple dichotomous choices (e.g., on-task vs. mind wandering, as in Chapter 4) to branching questions about the nature, valence, and content of one's internal experiences (Banks et al., 2016; Seli et al., 2017; Ye et al., 2014).

Chapter 4 sought to validate the use of experience-sampling probes as a means of empirically studying children's experience of mind wandering, an internal experience which can only be examined by way of subjective reports. Support for the validity of children's reports was found, with children's reports of mind wandering being associated with greater behavioural variability than their reports of being on-task. While more research is needed to identify best practices in the use of experience-sampling probes with children, the findings of Chapter 4, along with the limited number of other studies examining mind wandering in children (e.g., Keulers & Jonkman, 2019; Ye et al., 2014), offer support for the use of experience-sampling probes as a tool for empirically studying children's internal experiences.

The simple addition of experience-sampling probes to existing experimental and observational paradigms could yield important insights into the study of children's social development. With regard to the ambiguity surrounding the differences in children's performance between the social and non-social conditions in Chapter 2, giving children the opportunity to report on their attentional state and thought processes would be a clear means of identifying the processes responsible. Specifically, to evaluate the “cognitive busyness” account of children’s performance, probes could prompt children to report on the occurrence of task-irrelevant intrusive thoughts, hypothesizing that shyer children would report greater incidence of such thoughts under social conditions. Experience-sampling probes could similarly shed light on the nature of children’s internal attentional processes as they are manifest during dyadic interactions, as in Chapter 3. Intermittently pausing an interaction and prompting children to report on the contents and valence of their thoughts, the foci of their attention, and their perceptions of their burgeoning relationship with their peer could add a new insights into the analyses of peer interactions. Moreover, in a simulated interaction in which the experimenter manipulates the social events and stimuli to which a child is exposed, strategically presented experience-sampling probes could allow researchers to directly examine the consequences of various social events (the presentation of negative feedback, long latencies in conversational RT, etc.) on children’s occurrent thoughts.

Conclusion

Together, the three studies presented in this dissertation demonstrate how temperament, attention, and social context interact in meaningful ways to dictate children’s goal-directed behaviour across a variety of contexts. My research integrates a microscopic approach focusing on subtle changes in attention and behaviour over the course of milliseconds with a macroscopic approach that looks at behavioural dynamics at the level of global task performance and dyadic processes. The empirical methods I have developed offer new and exciting opportunities for studying attentional processes in both laboratory and applied contexts and provide a roadmap for a several lines of research going forward. By exploring the relations between internal experiences and their external behaviours, the interaction between trait characteristics and dynamic social contexts, and the relation between individual processes and dyadic outcomes, my research seeks to outline a holistic approach to the study of children's social development.

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