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## Sleep Restriction in Children and Executive Function Performance

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A thesis submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in Psychology

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## **Abstract**

Experimental sleep restriction yields data that shows how sleep loss causes declining daytime function in cognition and behaviour, yet few experimental studies have been conducted with preschool children between the ages of 3 and 5 years of age. During the preschool period children achieve important milestones in cognitive development while a significant minority also experience behavioural sleep problems regularly. There is no empirically-based consensus on the impact of reduced sleep in preschool children. To address this gap, parents of preschool children were recruited in a participatory design study to provide input in designing an accessible home-based experimental sleep study with conditions of sleep restriction and sleep fragmentation. Child participants in the experimental study wore actigraphs for 10 days to record their sleep during 7 days of baseline measurement, followed by 3 days of experimental measurement. Children were randomly assigned to a control condition, a 40-minute or 20-minute sleep restriction condition, or to a sleep fragmentation condition where they were kept awake for 20 minutes after first falling asleep. Daytime cognitive outcomes were assessed after the third experimental night using an assessment battery of developmentally-appropriate executive function measures of working memory, response inhibition, and delay of gratification. Contrary to expectation, less sleep relative to baseline was not associated with measured executive function performance decrements among children without pre-existing sleep problems. Experimentally imposing greater sleep restriction before assessment may be necessary to measure changes in executive functioning measures for this age group.

## Keywords

Sleep, Child Psychology, Participatory Design, Experimental Methods, Actigraphy, Executive Functioning.

## Summary for Lay Audience

Parents, caregivers and health professionals generally assume that negative outcomes such as poor behaviour, inattention, and more negative feelings such as anger or sadness result from shorter sleep. These assumptions are often applied to young children of preschool age (between 3 and 5 years old), particularly because this is an age group in a substantial minority of children delay bedtime or continue to wake during the night and require parents to attend to them before falling asleep again. However, there have still been very few studies that look at how getting less sleep affects young children during the daytime. In this research project, the overall goals were 1) to recruit parents of young children to find out how to design a study where parents would be willing and able to deprive their children of some sleep, and 2) to run this experiment with children between 3 and 5 years old to find out whether mild sleep deprivation affected children's performance on tasks that were related to the underlying development of thinking and behaviour. Parents of children in the target range were interviewed over the telephone in order to help plan the research. In the main research study, some children were assigned to receive less sleep, to be woken up at night, or to have no changes in their sleep. Children's variability in sleep duration on different days of the study resulted in challenges when comparing children's sleep restriction based on their assigned groups. The main research study found no differences in children's executive functioning performance based on sleep restriction; contrary to expectations, children who experienced greater sleep restriction during the experimental phase performed better on the measure of delay of gratification. More research will need to be conducted to determine how much sleep restriction may affect children's thinking and behaviour.

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A flow-chart summary of parents contacted, screened and excluded, including participants who did not complete the experimental protocol.

## Chapter 1

### 1 Introduction

Sleep is universal among mammals, and the youngest members of mammalian species typically spend more time sleeping compared to their adult counterparts (Siegel, 2005). Humans are no exception; infants engage in frequent episodes of sleep throughout the 24-hour day (Iglowstein, Jenni, Molinari, & Largo, 2003; National Sleep Foundation, 2004; Sadeh, 2003) and sleep continues to be a major activity of early childhood, occupying close to half of the 24-hour day (Iglowstein et al., 2003) until about the age of 5 years. Consequently, helping children to establish and maintain regular sleep is a major aspect of child care, especially during early child development. In view of the amount of time spent asleep in the early years, sleep's role in early child development has received relatively little empirical research attention until recently. Conversely, families with young children tend to focus on the importance of children's sleep, which has led to a surge in popular published advice for parents who wish to prevent sleep problems or improve their children's sleep (Ramos & Youngclarke, 2006). Dahl, an influential theorist in the domain of pediatric sleep, suggested that a historic lack of research into children's sleep may have been due to the assumption that nothing happens during a period when children do not appear active (Dahl, 1996b). A broader developmental perspective suggests that such a large amount of time spent in any activity, even a quiescent one, is likely to be important. Since the publication of Dahl's theoretical overview, more research on children's sleep has become available, but many questions remain about the specific contributions of sleep to early child development and functioning. This general introduction reviews what is known about sleep in early

childhood as it applies to how sleep, and particularly sleep restriction, might specific domains of cognitive development, particularly domains related to executive functioning skills.

### **1.1 Sleep in Early Childhood: A Brief Overview**

Caregivers and parents often notice changes in their young children's behaviour as a result of the children's apparent tiredness. As a result, fatigue or sleep deprivation in children was widely believed to have "a profound and well recognised impact on short-term behavioural patterns" (Pollock, 1994) even before larger empirical studies were conducted. Within the past few decades, there has been a greater interest in measuring sleep's effect on child behaviour. The role of sleep in the early years is important to clarify, not only because of the increased time spent asleep, but also because a substantial minority of young children appear to have difficulty sleeping.

Between 20% to 30% children between age 3 and 5 years old have problems either falling asleep in the evening, sleeping through the night, or both (Mindell, Meltzer, Carskadon, & Chervin, 2009; Petit, Touchette, Tremblay, Boivin, & Montplaisir, 2007; Taylor, Williams, Farmer, & Taylor, 2015). Together, these problems are often referred to as behavioural sleep problems, or dyssomnias of childhood (Anders & Dahl, 2007). Such problems are thought to arise due to unhelpful associations between external environmental stimuli and sleep initiation (Touchette et al., 2005; Zuckerman, Stevenson, & Baily, 1987). Behavioural sleep problems are not only common in preschool-aged children, but can also be long-lasting: for at least a subset of children, early onset sleep problems predict ongoing sleep problems into later childhood (Gaylor, Burnham, Goodlin-Jones, & Anders, 2005; Jenni, Molinari, Caflisch, & Largo, 2007; Williamson,



Mindell, Hiscock, & Quach, 2019; Zuckerman et al., 1987). Young children's reported sleep problems often co-occur with behaviour difficulties during the day. Such daytime difficulties include increases in emotional and behavioural problems (Bates, Viken, Alexander, Beyers, & Stockton, 2002; Bruni, Lo Reto, Miano, & Ottaviano, 2000; Conway, Miller, & Modrek, 2017; Gregory & O'Connor, 2002; Hiscock, Canterford, Ukoumunne, & Wake, 2007; Quach, Price, Bittman, & Hiscock, 2016; Reid, Hong, & Wade, 2009), poorer school readiness and cognitive performance (Kelly, Kelly, & Sacker, 2013; Meijer, 2008; Ravid, Afek, Suraiya, Shahar, & Pillar, 2009; Schwebel & Brezaussek, 2008; Touchette et al., 2007), and accidental injuries (Valent, Barbone, & Brusaferrero, 2001).

Given the variety of outcomes associated with sleep problems in early childhood, it appears that sleep plays a central role in children's healthy adjustment. However, exactly how sleep helps young children remains unclear. Therefore, the specific domains that sleep affects during early childhood to regulate and optimize behaviour and other daytime outcomes require a great deal of further empirical study. Furthermore, although there is a consensus that children need regular sleep, and that more sleep is recommended in younger age groups (Paruthi et al., 2016), there is little empirical research to demonstrate *how much* sleep disruption would impact child health or behaviour at any point in child development (Matricciani, Blunden, Rigney, Williams, & Olds, 2013). This is an important parameter to clarify. In order to better understand the relationship between child sleep problems and child behaviour problems, the impact of different degrees, or amounts, of sleep disruption needs to be examined. The previous published studies focusing on the outcomes of sleep problems in young children have used different

means of reporting sleep, with some involving parents reporting their child's general sleep, and others including more detailed records of sleep such as daily sleep diaries. As yet, there is no empirical evidence that reducing nighttime sleep in otherwise healthy preschool children leads to any specific changes in neurobehavioural performance, although some experimental studies with older children have reported that *increasing* children's sleep improves their performance on neurobehavioural measures such as reaction time, short term memory, and working memory (Sadeh, Gruber, & Raviv, 2003; Vriend et al., 2013).

Ronald Dahl proposed that sleep disruption or inadequate sleep causes problems in children's emotional and behavioural regulation due to sleep's essential role in "tuning," or regulating, neurobehavioural mechanisms (Dahl, 1996b). Dahl compared the human brain's complex systems and their interactions to an orchestra that requires periodic adjustment to play a piece of music with multiple instruments and parts. Using this metaphor, he likened the role of sleep to the tuning of the brain's instruments (*i.e.*, the brain must engage in various sleep stages in order to tune itself for optimal daytime functioning). Dahl's theoretical explanation cited contemporary evidence from clinical samples of children and adults who experienced sleep disturbances, as well as findings from pediatric case studies demonstrating dramatic improvements in children's behaviour when their sleep was improved through effective intervention. Crucially, Dahl emphasized a probable link between several neurobiological mechanisms that initiated and maintained sleep which, if disrupted, would prevent sleep from exerting its regulatory role within the brain. Additional research has confirmed the link between emotional-behavioural regulation and sleep (Buckhalt & Staton, 2011; Palmer & Alfano,

2017; Staples & Bates, 2011). Dahl noted that he could not suggest the specific neurobiological mechanisms that translated sleep disruption into daytime behavioural disruption, based on the research available when he wrote his review. However, he postulated that the central executive system, responsible for the behaviours related to executive function, could explain a great deal of the behavioural dysregulation related to sleep problems based on his theoretical framework. Therefore, Dahl's work provides a relatively early indication of a cognitive domain to measure relative to sleep in order to clarify whether sleep and sleep restriction might affect executive function in childhood.

Research studies that are designed to determine whether changes in sleep can cause changes in particular child behaviours, or vice versa, are essential to help untangle the relationship between sleep and daytime function in early childhood. According to Dahl's premise that neurobiological processes related to the central executive might be particularly vulnerable to sleep problems in childhood, research in this area should address whether differences in sleep obtained during the early years are related to differences in the behaviour related to executive functions. Much of the evidence showing an association between sleep in young children and problems with daytime function has relied on more global assessments of child behavioural functioning in relation to sleep, such as parent- and teacher-report measures of behaviour (Bates et al., 2002; Cremone et al., 2018; Paavonen, Porkka-Heiskanen, & Lahikainen, 2009) and general assessments of intelligence or school readiness (Jung, Molfese, Beswick, Jacobi-Vessels, & Molnar, 2009; Liu et al., 2012; Ravid et al., 2009). As evidence showing associations between sleep problems and behavioural or cognitive functioning problems has mounted, the measurement of more specific outcomes can guide improved theories

and models of sleep's role in early childhood adaptive functioning. Measurement of executive functioning represents an attempt to determine more precisely which underlying areas of function may be particularly sensitive to sleep disruption during the preschool years. The current research (Chapter 4) therefore represents some of the first groundbreaking research to answer whether an experimental paradigm of sleep restriction in young children can clarify whether sleep restriction deleteriously affects executive functioning performance.

Anders and Dahl (2007) proposed classification guidelines that could lead to a more objective understanding of how much sleep disruption in young children could constitute a clinically significant sleep problem. Anders and Dahl's review paper devoted to this topic (2007) describes in detail how adult criteria for behavioural sleep problems, or dyssomnias (unlike other sleep problems such as parasomnias and sleep apnea) are not appropriate for children because of the different developmental expectations for sleep during the toddler and preschool years. Their review highlights how little is known about sleep and sleep disorders in young children, motivating the need for classification guidelines to highlight objective, measurable aspects of sleep. Such guidelines were presented to provide a focus for researchers hoping to determine which aspects of sleep disruption might lead to reliable, clinically significant changes in children's behaviour and functioning. One of the most important dimensions of sleep that Anders and Dahl highlighted as a target for researchers to measure and track was objective sleep timing. They also suggested that criteria should be developmentally sensitive, where children at older ages would be classified as having more significant problems with the same objective amount of sleep disruption as a child at a younger age (See Table 1.1 for a

summary of criteria for younger preschool children). In this classification system, the number of minutes of sleep that children missed due to either delayed/restricted bedtimes, or to waking at night and failing to return to sleep quickly becomes an important aspect of determining a problem. However, at the time of this publication, Anders and Dahl noted that much of the research to determine the impact of sleep disturbance, in terms of sleep disruption timing ranging from 10 minutes to 30 minutes, had yet to be done. In other words, the number of minutes chosen to serve as benchmarks for research had to be based on expert consensus, given that there was little empirical data on the number of minutes of sleep that was either optimal or typical for children in the infant, toddler, or preschool range. Surprisingly little has changed in the 13 years since their review. Current guidelines recommending sleep for children outline a range of hours, not minutes, children should spend asleep. These guidelines continue to be primarily based on parent-report surveys and clinical experience from small samples (Matricciani et al., 2013; Paruthi et al., 2016). Therefore, research that measures children's sleep at the level of minutes asleep in the context of baseline, as well as restricted sleep, will contribute most to useful knowledge that addresses the need for empirically-based consensus guidelines to identify early child sleep problems.

Table 1.1

*Summary of Developmentally Sensitive Criteria for Night Waking and Sleep Onset  
Dyssomnia in Young Children from Anders and Dahl (2007).*

Dyssomnia Type	Perturbation	Disturbance	Disorder
	one episode per week for 1 month	two to four episodes per week for 1 month	five to seven episodes per week for 1 month
Night Waking	$\geq 2$ awakenings/night	$\geq 2$ awakenings/night	$\geq 2$ awakenings/night
$24 \leq 36$ months old	$\geq 20$ mins awake total	$\geq 20$ mins awake total	$\geq 20$ mins awake total
Night Waking	$\geq 2$ awakenings/night	$\geq 2$ awakenings/night	$\geq 2$ awakenings/night
$> 36$ months old	$\geq 10$ mins awake total	$\geq 10$ mins awake total	$\geq 10$ mins awake total
Sleep Onset	$> 30$ mins to be asleep	$> 30$ mins to be asleep	$> 30$ mins to be asleep
$> 24$ months old	Parent present to sleep  More than 2 reunions (ex protests, struggles)	Parent present to sleep  More than 2 reunions (ex protests, struggles)	Parent present to sleep  More than 2 reunions (ex protests, struggles)

## 1.2 Measurement of Executive Function in the Context of Child Sleep

Executive function (EF) is a particularly compelling area to study in relation to preschool sleep because of advances in developmental science that have tracked the emergence and expansion of several important EF skills during the preschool period. Broadly speaking, EF constitutes a group of related abilities that develop gradually throughout childhood and into adolescence, and are related to organization, novel

problem solving, and inhibiting automatic behaviour in the service of a particular goal (Carlson, 2005; Garon, Bryson, & Smith, 2008; Lehto, Juujarvi, Kooistra, & Lulkkinen, 2003). Several decades of research in the function and development of EF have led to a variety of structured assessments to assess EF skills in children at different ages and stages of development. Many of these assessments were first devised as a way of tracking the developmental emergence of skills, and therefore were designed and conceptualized in terms of pass-fail, or dichotomous outcomes. For example, the well-researched Dimensional Change Card Sort (DCCS) task (Zelazo, 2006) determines whether children can or cannot shift to sorting cards by one dimension (e.g., shapes printed on cards) after they have first been taught successfully to sort based on a different dimension (e.g., the colour printed on the cards). The DCCS is a developmentally sensitive and useful measure of EF skills (i.e., set shifting), but has mostly been used in contexts to show that younger children are unable to make the shift required to sort the same cards by a new dimension, while older children are able to make this shift.

Few measures of any type of EF have been used in studies that measure preschool children's sleep over the course of several days. Dichotomous measures of EF, such as the DCCS, could be more difficult to use as an outcome measure of sleep disruption compared with measures of EF scored on a continuum. In other words, it was expected that the most likely outcome for emerging EF skills in the context of sleep disturbance or disruption would be a slight decline in EF skills, rather than a loss or regression in performance characteristic of an earlier developmental stage. Furthermore, measures of EF that can be scored on a continuum (i.e., those that have several items of a similar sort that award points for each item summed as a total score) should be more likely to capture

slightly poorer performance in EF skills, without losing any potential information if children were to experience serious decrements in performance as a result of sleep loss. Therefore, the outcome measures chosen for this sleep research with young children were those that were scored on a continuum (an ordinal or interval scale).

### **1.3 Summary of Current Research**

The current project brings together research from developmental psychology, pediatric sleep research, and sleep experimental methodology to address the impact of sleep on cognitive performance in young children. Firstly, this research was designed to clarify how much sleep disruption or restriction could affect daytime outcomes through the choice of sleep measurement: actigraphy and sleep diaries were used to measure children's sleep over several days, following the recommendations of experts in the field of pediatric sleep measurement (Acebo et al., 2005; Anders & Dahl, 2007). This measurement approach allowed the observation of changes in children's sleep that could reflect proposed research definitions for sleep perturbations and disturbances that had been previously proposed (Anders & Dahl, 2007), but not empirically studied in terms of their impact on young children. Secondly, the outcome measures selected to determine the impact of sleep changes on children were chosen to reflect the developing cognitive domain of executive function, an area theorized to explain some of the associations between negative behavioural outcomes and sleep problems in young children (Dahl, 1996b; Turnbull, Reid, & Morton, 2013). Executive function has also received some preliminary empirical support as an outcome of sleep restriction in older children (Vriend et al., 2013), but the effect of sleep on executive function has not been studied in children between the ages of 3 and 5 years, leaving a gap in our understanding of this



developmental period. Thirdly, this research uses primarily a between-subjects experimental design to determine the effect of sleep on executive function performance, with more child participants than in any previously published study of children within this age range. This increased sample size provides more potential information about sleep measurement and the structure of typical sleep patterns within this age group than more narrowly controlled experimental studies with younger children that have been published (Berger, Miller, Seifer, Cares, & LeBourgeois, 2012; Miller, Seifer, Crossin, & LeBourgeois, 2015). Finally, this research includes the only reported attempt to study sleep disturbance in an experimental paradigm of sleep fragmentation, or waking children who are already asleep. This novel condition was included as part of the experimental design to reflect the reality that behavioural sleep problems for many preschool children involve waking up at night and having difficulty returning to sleep. Having no information about whether fragmented sleep is the same or different from having less sleep overall in early childhood makes this an important, yet so far unstudied empirical question.

The purpose of the current research was to determine whether reducing sleep in children between the ages of 3 and 5 years old would result in differences in performance on tasks related to executive functioning. An experimental model of sleep changes that would allow for conclusions about how common behavioural sleep problems was chosen; namely, children were assigned to conditions of sleep restriction (in which they would receive less sleep than typical) or to conditions of sleep fragmentation (in which they would experience interrupted sleep during the night). This was the first attempt to

conduct this type of experiment with children in the 3- to 5-year-old age range that involves sleep changes to nighttime sleep over a series of days.

Accordingly, the first phase of this research involved a participatory design study to allow parents to provide feedback and suggestions for the protocol. Parents' comfort and acceptance of the procedures, and of a range of potential sleep conditions was investigated, as well as a discussion of parent concerns to design the most effective protocol possible for participant families. The process and results of the participatory design are reported in Chapter 2.

The measurement of children's sleep at baseline as well as in experimental conditions provides a useful contribution to the literature, given the current paucity of empirical data on sleep patterns in young children, as well as relevant considerations for experimental sleep designs using 3- to 5-year-old child participants, of which there are still very few in the literature. Chapter 3 illustrates the properties of sleep we were able to measure in children using actigraphy, as well as the consequences for interpreting the experimental group sleep manipulations and lessons for other researchers who wish to conduct experiments in this population.

Chapter 4 provides the main rationale, and statistical analyses of the sleep differences measured in the child participants relative to the outcome measures of attention and executive function. Finally, Chapter 5 summarizes the overall research project in terms of its implications for future researchers and the contribution of these data to the overall field of pediatric sleep research.

## Chapter 2

### 2 **Dreaming of New Research Approaches: The Application of Participatory Design to Experimental Sleep Restriction in Preschoolers**

Research with children involves careful planning, especially when developing new procedures that require active participation from both parents and children. Without an understanding of how parents perceive a research protocol involving their children, certain methods and design features that seem reasonable to investigators might discourage potential parent participants. Parents may have more concerns and questions about involving younger children in sleep research protocols compared with older children. Available research indicates that parental cognitions are related to parenting in general (Azar, Reitz, & Goslin, 2008) and child sleep management in particular (Coulombe & Reid, 2012; Morrell, 1999). This is especially true for children who have not yet reached school age, and are well known to have reduced self-control skills compared with older children (Eisenberg et al., 2004). Therefore, before embarking on a study involving voluntary sleep restriction and fragmentation amongst preschool-age children, we sought the input of parents on specific aspects of a proposed sleep study protocol. This chapter describes the participatory design approach used to include parent feedback in the study design.

#### 2.1 **Participatory Design in Human Research**

With changes in technology and planning new procedures, seeking feedback from all who will be involved in a research study can be helpful. Participatory design (Scariot, Heemann, & Padovani, 2013) involves the users of new systems to plan and review procedures with individual users before such systems are implemented. Participatory design (Spinuzzi, 2005) is a term that has come from qualitative research methods, and

has been widely used in information technology development (Clemensen, Larsen, Kyng, & Kirkevold, 2007).

Patient engagement in clinical service design and delivery is a similar concept to participatory design. Patient engagement has been a focus in the United Kingdom for a number of years (Boyle & Harris, 2009; Hanley et al., 2004; Needham & Carr, 2009), and patients contributions are included more often in research, particularly clinical trials (Gamble et al., 2014; Marshman et al., 2012). In Canada, the Canadian Institutes of Health Research (Canada, 2014) recently launched a Strategy for Patient-Oriented Research (SPOR). The SPOR states that patient engagement is “(m)eaningful and active collaboration in governance, priority setting, conducting research and knowledge translation”(Canada, 2014). Patient engagement has many similarities to participatory design research: the inclusion of the people in the design who will need to use a system, or participate in a treatment, helps to anticipate some participant concerns and implementation obstacles. Despite the potential benefits of having patients participate in research design for a treatment or experimental study, few published studies describe including participants at the design stage (Meyer, 2000; Vingilis et al., 2003).

Applying participatory design involves parent participants for developmental research in a much more active role compared to a pilot study. Unlike pilot studies (Foster, 2013), participatory design actively includes users or participants in the protocol to help design the study using feedback. This model of research development is more collaborative than the traditional pilot study, where researchers oversee the project and identify difficulties in the protocol with less input from participants and users. Our plan was to develop and implement an experimental study of sleep restriction in children

between 3 to 5 years of age. We recruited community parents to help assess parental willingness to participate in the research, and to inform specific elements of the study protocol. This is a novel application of participatory design in non-intervention child development research.

## **2.2 Preschool Experimental Sleep Research**

Experimental studies can establish causal associations between variables, and can often do so with smaller sample sizes than other types of research, such as longitudinal designs with statistical controls. Experimental sleep restriction and deprivation has been very useful in showing the effects of sleep in adults, showing that sleep deprivation reduces the ability to learn new material (Walker, 2005), impacts emotional processing (Baran, Pace-Schott, Ericson, & Spencer, 2012), and disrupts executive functioning (Jones & Harrison, 2001; Martella, Casagrande, & Lupiáñez, 2011; Tucker, 2010). More recently, experimental sleep studies have been conducted with school-aged children (Fallone, Acebo, Seifer, & Carskadon, 2005; Gruber et al., 2011; Sadeh et al., 2003), and children as young as six years have participated experimental sleep changes at home (Fallone, Seifer, Acebo, & Carskadon, 2002). One recent study has used an experimental protocol of nap deprivation in young 3-year-old children, conducted in day care settings, to investigate the role of sleep in cognitive and emotional processing (Berger et al., 2012). However, there have been no experimental sleep studies with older preschool children (i.e., 3- to 5-year-olds), leaving a fundamental gap in our understanding of how sleep restriction affects this age group. Due to sleep changes between childhood and adulthood, as well as ongoing cognitive and neurological development, findings from experimental studies of adults and older children may not be directly relevant to the

relationships between sleep and daytime functioning in younger children (Turnbull et al., 2013). Therefore, one of the best methods to determine the effects of sleep restriction on young children is to study them directly within an experiment where they experience differing amounts of sleep restriction.

The initial plan for our experimental study was random assignment to conditions of control, sleep restriction and sleep fragmentation. The sleep restriction conditions we considered involved delaying children's bedtime by 20 minutes per night or 30 minutes per night for at least two nights. This is similar to experimental sleep restriction previously conducted with older children (Fallone et al., 2005; Sadeh et al., 2003), but involving shorter durations and a greater variety of conditions involving different amounts of sleep change. The time period of 20-30 minutes corresponds to the delay in sleep onset used in current definitions of behavioral insomnia for preschoolers (Anders & Dahl, 2007). In addition, due to the frequency of reported night waking problems in the preschool years (Hiscock et al., 2007; Ottaviano, Giannotti, Cortesi, Bruni, & Ottaviano, 1996; Petit et al., 2007), we wished to include conditions in which children were woken from sleep at night to study an experimentally-manipulated form of sleep fragmentation. We planned to include a sleep fragmentation condition involving 20 minutes of being awake each night for two consecutive nights and another condition involving 30 minutes awake. Parent collaboration and feedback on the sleep fragmentation procedure was essential: experimental sleep fragmentation in children has not previously been undertaken, despite its potential relevance to the impact of early child sleep problems. Furthermore, studying sleep fragmentation experimentally, in comparison with sleep restriction, has the potential to determine the clinical significance and impact of night

waking in early childhood beyond the effect reducing sleep duration. The goal of the planned study was to investigate child neurocognitive outcomes in relation to sleep.

### **2.3 Illustration of Participatory Design for Pediatric Experimental Planning**

The purpose of the present study was to collaborate with parents using a participatory design framework. Within this framework, we hoped to learn parents' concerns and opinions about the planned experimental research in order resolve as many potential concerns and obstacles as possible before undertaking the sleep study with 3- to 5-year-old children in the community. We created a semi-structured telephone interview to solicit feedback from parents of young children within the age range of our target sample. Interview questions included quantitative information, in which parents reported specific amounts of time they would be willing to restrict children's sleep, as well as qualitative information about their opinions regarding the procedures for the planned research study. Our approach is therefore best described as a semi-structured interview study using elements from qualitative research methods (Patton, 2015), within the overall framework of participatory design.

## **2.4 Method**

### **2.4.1 Participants**

**Recruitment.** The University of Western Ontario Psychology Departmental Research Ethics Committee reviewed and approved all procedures for the current study. Parents were recruited through online advertisement and letters of information distributed to community daycare and preschool programs. Parents who had previously participated in Developmental Psychology Research at the authors' institution and had agreed to be contacted for future research were also approached to participate in the study. The first

author explained the study to these parents over the telephone, including the details of the study needed for parents to provide verbal consent to the interview. Screening questions verified whether parents met the inclusion/exclusion criteria, and those who were eligible completed the telephone interview. Of the 34 parents who expressed interest in the study, 30 completed the telephone interview; 4 were unable to be re-contacted for the telephone interview after several attempts ( $n = 4$ ). Of the 30 parents contacted, 11 were excluded based on the child's sleep habits ( $n = 9$ ; see Exclusion Criteria below), or because their child was not currently between 3 and 5 years old ( $n = 2$ ).

**Inclusion Criteria.** Parents could participate in the interview if they reported that they were comfortable with spoken English, and had at least one child currently between the ages of 3 and 5 years old.

**Exclusion Criteria.** Parents were excluded if they reported that their child had a diagnosis related to a development or behavioral disorder (e.g., Attention Deficit Hyperactivity Disorder), a chronic medical condition (e.g., asthma), obstructive sleep apnea, restless legs syndrome, periodic limb movement disorder, or narcolepsy. Parents who reported that their child had a behavioral sleep problem were also excluded. Behavioral sleep problems were defined as bedtime resistance that delays bedtime, or night waking (at least two times per night) that occurred more than twice a week during the previous month, and lasted at least 20 minutes on average per episode (Anders & Dahl, 2007). No children were excluded from the study based on bedtime resistance, but  $n = 5$  were excluded based on night waking. Parents who reported that their child regularly slept in the same bed with another family member (parent or sibling) were also



excluded ( $n = 4$ ), as co-sleeping may sometimes occur in response to child sleep problems (Lozoff, Askew, & Wolf, 1996).

**Study Sample.** Parent participants (18 mothers and 1 father) had children who ranged in age from 3.0 to 5.75 years old ( $M = 4.17$ ,  $SD = 0.91$ ). The majority of parents reported they were married ( $n = 17$ ) or common-law ( $n = 1$ ); one parent was single. The majority of parents also reported that they had completed a college or university program ( $n = 15$ ; 79%), with three reporting some post-secondary education and one having completed high school only. Two parents indicated that they preferred not to answer the question about family income; of those who responded almost half ( $n = 9$ ) reported an annual household income of over \$100,000 and only three parents reported an income of less than \$60,000. For comparison, 2% of families with children in the same geographic region reported income over \$100,000 and 74% of parents completed a college or university program (Statistics Canada, 2006).

Parents reported that their children slept between 10.1 and 13.1 hours per night on average ( $M = 11.2$ ,  $SD = 0.67$ ). Only three parents reported that their child napped every day: eight parents reported their child napped only on certain days of the week (e.g., only on the weekend, or on the days that they attended daycare); the remaining parents ( $n = 8$ ) reported that their children did not nap.

#### 2.4.2 Procedure

**Semi-Structured Interview.** The interview had two parts. In the first part, parents were asked to describe their family demographics, family composition, parent work schedules, and the child's typical sleep and childcare schedules. In the second, and

core part of the interview, parents were asked for their opinions and thoughts on specific aspects of the proposed experimental protocol including delaying their child's bedtime and waking their child up after he or she had fallen asleep. Parents were also asked about other aspects of the procedure, such as the child's use of an actigraph motion monitor (Acebo et al., 2005) and keeping a diary for sleep measurement, participating in a home visit to measure child neurobehavioral performance, and randomizing each child to different experimental groups. As all of these other procedures have been used in previous child studies, we report only parent views on experimental sleep restriction and fragmentation here.

Parents were asked about the planned experimental sleep restriction before sleep fragmentation. For sleep restriction, parents were first told that in the study parents would be required to "push their child's bedtime later, but to make sure they wake up at the same time as usual and make sure they do not take any extra or any longer naps." Parents were then asked how long they would be willing to delay their child's bedtime each night, for how many days in a row they would be willing to do this, and to report the latest time they would be willing to put their child to bed for a study of this nature. Parents were prompted to share any problems they felt they would have with delaying their child's bedtime, and any concerns about the procedures in general, including effects they anticipated in themselves, their child, or their other family members. Finally, parents were asked to rate, on a scale of 1-100 their willingness to delay their child's bedtime 30 minutes later for two nights.

For sleep fragmentation, parents were told that they would be asked to "wake their child after he or she had gone to sleep and keep them up for a brief period of time,"

with the same stipulation that the child would not be allowed to make up this extra sleep by sleeping later the following morning or with extra napping during the study. Parents were then asked what times during the night they would be most and least willing to wake their child, the amount of time they would be willing to keep their child awake, the number of times they would be willing to wake the child up per night, and the number of days they would be willing to do this. Parents were then prompted to share any problems they felt they would have with waking their child from sleep and keeping them awake, including any effects they anticipated in themselves, their child, or their other family members. The interviewer also described potential resources the research team could offer, such as telephone coaching or self-help resources to deal with potential sleep issues resulting from the study if parents were concerned about participation changing their child's sleep. Finally, parents were asked to rate, on a scale of 1-100 their willingness to wake their child and keep him or her awake for 10 minutes each night for two nights in a row.

#### **2.4.3 Coding of Interview Data**

Parent interviews were transcribed verbatim from audio-recordings of the interviews. The first author used a thematic analysis approach to summarize the qualitative data (Braun & Clarke, 2006). She reviewed sections of the interview transcripts where parents described their opinions regarding participation in the hypothetical sleep restriction and sleep fragmentation procedures. Parent concerns were identified and summary descriptions of these concerns were made separately to capture themes that could describe parental concerns that appeared across cases (Harding, 2013). Seven distinct themes were identified for parents' concerns about sleep restriction, and

eight themes were identified for parents' concerns about sleep fragmentation (see Tables 2.1 & 2.2). Once these themes had been identified, the transcripts were reviewed again, numerical codes were added to the transcripts to identify individual parent statements that referred to each theme, and exemplar quotes were chosen (Harding, 2013; King & Horrocks, 2010). Two research assistants aware of the purpose of the study reviewed unmarked transcripts to check for any additional parent concerns; no new themes were identified in this review.

## **2.5 Results**

### **2.5.1 Perspectives on Experimental Sleep Restriction**

Parents varied in how many minutes (15 to 120) they would be willing to delay their child's bedtime, and the majority of parents reported they would be willing to extend their preschooler's bedtime at least half an hour. There was a wider range of variability in how long parents would be willing to delay children's bedtimes than we anticipated, with some parents saying they would only be willing to change their child's sleep a small amount, while others were willing to keep their child awake for up to 2 hours past the regular bedtime. The most commonly reported parent concerns were a negative effect on the child's mood and behavior following sleep restriction; "small little things that wouldn't upset him now would definitely upset him." One parent specifically described concerns about hyperactive behavior following sleep restriction: "if she doesn't go to bed early, she gets a real second wind and gets really wired and silly and goofy." Table 2.1 summarizes the concerns of parents along with exemplar quotations from telephone interviews.

**Table 2.1***Parent Concerns about Sleep Restriction in Preschool Children*

Concern	Example	<i>n</i> *
Negative child mood	“I just think he’d be in a bad mood.” “I know he would get grumpy.”	13 (68%)
Problematic child behavior	“...severely grumpy, like throwing huge temper tantrums” “...tends to poke at his brother or other kids around him if he hasn’t slept as well.”	7 (37%)
Conflicts with adult/ family schedule	“I’m afraid she’d stay up and then I wouldn’t get to sleep.”	7 (37%)
Child falling asleep	“If we go for a car ride anywhere if he’s tired he will conk completely out.”	7 (37%)
Child health concerns	“If she’s tired, sleepy, she’s probably not going to eat as well.” “I wouldn’t want to be forcing him to stay awake if he needed to sleep off a bug.”	5 (26%)
Long term effects on sleep	“Three days of consistency will reset a child’s sleep schedule. Two we can handle ...but three [is] crossing over into a new routine.”	3 (16%)
Effect on child’s sibling	“It might cause a rift if I let him go to bed later than his brother.”	2 (10%)

*n*\* = Number of parent participants who endorsed each theme/concern in interview.

Some parents did not anticipate that sleep restriction for a short period would have a negative effect on their child at all: “I don’t think she’d have any trouble

adjusting, I don't think she'd suffer from lack of sleep." In contrast, one parent had strong views about the potential negative consequences of changing a child's sleep for three days instead of two:

I'm completely convinced that you can change a child's schedule in three days. In all of my children... if we let them fuss for three nights that resets their schedule...I'm a firm believer that three days of consistency will reset a child's sleep schedule. Two we can handle and get back from, but three is crossing over into a new routine.

This quotation illustrates a more extreme opinion than most parents expressed. The same parent described how it would take "at least a week to sort them back to normal" and did not feel that any support offered from the research team (e.g., telephone support and treatment resources to reinstate desired sleep habits) would reduce her unwillingness to change her child's sleep for three days or more. This parent described the main source of her unwillingness as "I need [the children] to function at a certain level so that I could function at a certain level." Other parents had concerns that changing child sleep might result in longer-term effects on sleep schedules, without expressing total opposition to hypothetical changes. For example, one parent explained "I wouldn't want her to get used to it, I wouldn't want to have a fight on my hands to get...her back to her normal bedtime."

### 2.5.2 Perspectives on Experimental Sleep Fragmentation

Parents were generally less willing to wake their children at night and keep them awake for a short period of time, compared with their willingness to delay their children's bedtime. One parent reported that she would not wake her child at night because her work schedule required that she go to bed early in the evening in order to wake up at 3:30 am;

other parents were unwilling to wake their children because they reported it would upset and confuse their child, or because they felt waking their child from sleep at night was inappropriate. Table 2.2 summarizes the concerns of parents regarding experimental sleep fragmentation.

**Table 2.2**

*Parent Concerns about Sleep Fragmentation in Preschool Children*

Concern	Example	<i>n</i> *
Child not falling back to sleep	“He would get into playing and it would be more difficult to get him back into bed.”	11 (58%)
Unable to wake child	“He’s really difficult to wake up when he’s sleeping so I don’t know that I’d be able to keep him up.”	8 (42%)
Waking would confuse/upset the child	“She’ll probably get really angry.” “She wouldn’t understand why I’m waking her up.”	8 (42%)
Adult/family schedule	“When the children go to bed it allows us to watch a movie or spend time as a couple.”	6 (32%)
Long term effects of waking	“I think that might affect his sleep in the future.” “she might wake up on her own for a period of time.”	5 (26%)
Philosophical disagreement with waking child	“I just don’t think it’s very fair of me to do that to her.” “I don’t think I would voluntarily wake any sleeping kid up.”	4 (21%)
Negative child mood	“he might be grumpy the next day.”	3 (16%)
Child wakes others	“if he does get woken up ...sometimes he cries and I don’t want to run the risk of waking my other child up.”	3 (16%)

*n*\* = Number of parent participants who endorsed each theme/concern in interview.

Most parents who were willing to wake their children at night were only willing to do so once during the night, although a few reported that they would be willing to

wake their child twice, or even three times. Overall, parents reported that they would be willing to keep their children awake for less time at night (2 to 60 minutes) compared to delaying children's bedtime. One theme that emerged was quite different for waking versus sleep restriction: some parents described their opposition to this procedure as a fundamental disagreement with waking a sleeping child. Waking a child was described as an "unnecessary burden," and parents empathized with children's feelings of upset and discomfort at being woken at night: "I know I don't like to be woken up when I'm asleep and I know she's pretty similar that way." Another parent described waking someone from sleep as "the most horrible thing to do to somebody." Other parents brought up practical obstacles. In particular, parents were unsure that they could wake their child: "He's really difficult to wake up when he's sleeping" – or get him/her back to sleep – "it might be hard to get him back to sleep once I actually woke him up". A few parents noted that a practical difficulty with waking their children at night was a lack of appropriate activities for the child, which would be needed to keep the child awake – "we don't usually make the bed a place for him to play."

**The effects of providing basic sleep information.** Due to the concerns that parents expressed regarding waking their child, information about sleep stages was added to later interviews ( $n = 7$ ) to see if this would affect willingness to participate for parents who expressed concerns with a sleep fragmentation procedure. Specifically, if a parent expressed concerns with waking their child, phases of deep sleep and light sleep were explained. Then, parents were informed that the study procedure would involve asking them to wake their child at a time that should coincide with a lighter phase of sleep, making it easier to wake the child. Parents were also informed more explicitly that the



purpose of waking children was to learn about the possible effects of night waking in young children with chronic sleep problems. When provided with this additional information, all parents who expressed concerns ( $n = 6$ ) were more willing to wake their child at night: “obviously it would be easier [if the child was sleeping lightly], yes”.

## **2.6 Discussion**

### **2.6.1 Overview of Parents’ Views and Suggestions**

There are no existing experimental nighttime sleep restriction studies with preschool children; but some studies using nap restrictions have been conducted (Berger et al., 2012; J. C. Lam, Mahone, Mason, & Scharf, 2011; Miller et al., 2015). To the best of our knowledge, sleep fragmentation has not been previously used as an experimental sleep research procedure with children of any age. Therefore, we used a participatory design method to collaborate with community parents to design an appropriate protocol that would be as acceptable and feasible as possible for children between age 3 and 5 years old. The interviews yielded valuable information about parent opinions and concerns relevant to the feasibility of conducting experimental sleep research with community preschoolers. More broadly, the findings of this study illustrate how participatory design can assist researchers in planning experimental studies involving active participation from parents and their young children.

Most parents raised some concerns about the potential impact of sleep restriction on their child, and these concerns were similar to associated features of child sleep problems (Bates et al., 2002; Bruni et al., 2000; Hiscock et al., 2007). In addition, we learned that some parents were fundamentally opposed to waking their child. These parents described their concerns in terms of their beliefs, referring to a procedure of

waking a sleeping child as inherently wrong, rather than simply inconvenient. Night waking during the preschool years is quite a common occurrence for at least a substantial minority of children (National Sleep Foundation, 2004; Petit et al., 2007), and the children in our sample were not currently experiencing night waking. Therefore, the participatory design approach showed us how important these concerns were to parents, and gave us the opportunity to collaborate with parents to solve them.

Parents who had reservations became more willing to participate when we discussed the broader goal of the study: to understand the effects of poor sleep in children who wake at night regularly. This change in willingness illustrates that including potential participants in the design of an experiment helps to improve the messaging to parents. This is particularly important for pediatric research. It was not enough for parents to know what they and their children would be asked to do in the course of research; they also wished to know why they would be asked to do it. Improving recruitment and retention enhances the validity and statistical power of research findings, particularly for community studies (Hinshaw et al., 2004; Mapstone, Elbourne, & Roberts, 2002; Prinz et al., 2001). This participatory design study provides an example of how involving parents in the design of pediatric research can lead to protocols that should enhance recruitment.

### **2.6.2 Participatory Design and Pediatric Research**

Our participatory design allowed us to plan a study that was most likely to be acceptable to parents and one that they would be able to implement. Many parents were willing to delay their children's sleep for longer periods than we anticipated; therefore, we determined that we could extend the degree of experimental sleep restriction for a

second sleep delay condition from 30 minutes to 40 minutes, and increase both sleep restriction conditions from 2 nights to 3 nights. However, because sleep fragmentation was less acceptable to most parents, we decided to include only one sleep fragmentation condition where children would be woken for 20 minutes for 3 nights. Although this represented a longer period than some parents were willing to wake their children, we also incorporated several elements in the sleep fragmentation condition to help parents feel more comfortable with the procedure. First, we decided to include a description of child sleep cycles and the goal of waking children up during a light phase of sleep for the sleep fragmentation procedure – 75 minutes after falling asleep according to normative data on child sleep stages (Scholle et al., 2011). We also included within this description that waking children at night would help us to gain information about how children with chronic night waking problems were affected and that this information was otherwise difficult for researchers to obtain. Second, we decided to provide a quiet activity for parents to do with their children during the experimental night waking phase to help parents who were concerned about keeping their child awake when this was not part of their routine. Third, we included an information sheet for parents assigned to the sleep fragmentation condition that reviewed common parent questions and concerns about the night waking procedure. The second and third elements were included primarily as a result of the parent feedback we received within this participatory design.

The current study was not specifically designed to investigate parent beliefs about children's sleep, but the importance of understanding parental cognitions regarding planned research procedures emerged as a key theme. Beliefs are highly connected to motivation, decision making and behavior (Armitage & Conner, 2001). This is true of

different aspects of parenting, including management of children's sleep (Azar et al., 2008; Coulombe & Reid, 2012; Johnson & McMahon, 2008). Our protocol changes, informed by parent feedback, highlight the advantages of including parents in the design of community child research studies, particularly those that involve parent commitment. Involvement of children and parents has been examined in the planning of clinical trials involving these participants (Hinshaw et al., 2004; Marshman et al., 2012), but is rarely used in planning pediatric behavioural research. For studies of young children that involve either parental commitment (e.g., ongoing behavior logs/diaries) or the implementation of a child intervention, we believe that participatory design provides a valuable method for anticipating and addressing obstacles in planned research methodology with pediatric populations. Including parents in the design of a child study allows them to contribute their expertise regarding their own life and children, to feel more engaged in pediatric research, and to provide valuable information that researchers may overlook. Unlike a typical pilot or feasibility study, the participatory design allows parents to be actively involved in the creation of study procedures that will best suit their family in the community.

### 2.6.3 **Limitations**

Though we attempted to interview a diverse community sample, participants were primarily married mothers with higher family income, relative to the overall community where we conducted the study (Statistics Canada, 2006). Some of this restrictiveness may have been due to the fact that sleep problems are more common among young children living in families with lower socio-economic status (Hale, Berger, LeBourgeois, & Brooks-Gunn, 2009), and we excluded children with sleep problems. In spite of the

higher income and educational attainment of some of our sample, a number of concerns were brought forward in the interviews that allowed us to revise our experimental study protocol. Also, there were gaps in parents' knowledge about sleep in young children, and further information about sleep in the early years seemed to reassure concerned parents about potential participation in the research protocol.

Qualitative research and analysis can yield rich information about participant views (Patton, 2015), and a fuller qualitative approach could have extracted further meaning from parent interviews. Given our overall objective to inform a future quantitative study and our background in quantitative methods, we used an approach that we felt would best guide the prospective quantitative study. Although additional meaning of parent beliefs could have been elicited in the study interviews, we hope that this approach nevertheless suggests further research ideas to those who wish to work within either a quantitative or qualitative framework.

#### 2.6.4 **Further Research Directions**

The participatory design revealed very strong parental views about waking children from sleep, but only in a subset of our sample. Future research could determine whether strong beliefs about potential harm from this procedure are related to other parent beliefs and characteristics. As we discovered through the current study, parents can have strong views on the potential impact of a research procedure on their children. Therefore, including parents as collaborators in the participatory design framework allowed us to identify these views before the study and design a procedure that would make the best use of resources for planning and carrying out the study. In order to conduct effective pediatric research that involves experimental manipulation, parents

must be willing partners. Our study revealed not only how we could improve our planned research to address parent concerns, but also that we may be unaware of strong parental views on sleep, even among parents whose children do not have ongoing problems.

Researchers in this area would be well-advised to continue using the participatory design approach in their design of pediatric experimental research to determine where additional information may be beneficial to parents and help them manage their concerns.

## Chapter 3

### 3 **A Home-Based Experimental Sleep Restriction Protocol with 3-to 5-year-old Children: Implementation and Adherence**

Sleep is believed to support several essential neurological functions, including neuroplasticity and emotion regulation in child development (Jan et al., 2010; Jenni et al., 2007; Miyamoto & Hensch, 2003; Siegel, 2005). Young children spend more time sleeping than older children and adults, and this extended sleep appears to support the rapid pace of early neurological development (Turnbull et al., 2013). At the same time, the preschool years (3- to 5-year-olds) are a time when 20-30% of children experience behavioral sleep problems (Hiscock et al., 2007; Petit et al., 2007), with some studies suggesting even greater prevalence (Sadeh, Mindell, & Rivera, 2011). Given that sleep problems are common, understanding the impact of reduced sleep on children's daytime functioning is important, particularly if adequate sleep supports child development. This chapter describes the measured sleep parameters in the sample of child participants, the methods to determine experimental changes in children's sleep relative to baseline, and the potential impact of child and family characteristics on children's adherence to experimental phase sleep changes.

#### 3.1 **Sleep Measurement in Children**

A substantial body of correlational literature has associated early child behavioral sleep problems and shorter sleep durations with negative consequences in emotional, behavioral, and cognitive domains (Bates et al., 2002; Calhoun et al., 2012; Hiscock et al., 2007; Lavigne et al., 1999; Liu et al., 2012; Paavonen et al., 2009; Touchette et al., 2009; Yokomaku et al., 2008). However, most research does not closely track how much

sleep loss children experience from these sleep problems. Without a clear sense of how much sleep restriction disrupts young children's adjustment, we cannot determine the boundary between benign sleep variation at young ages, and potentially clinically significant problems.

Our understanding of how sleep maintains optimal daytime function has been enhanced through a variety of study designs. Experimental designs directly manipulate sleep time to determine causal relations between sleep restriction and daytime behavior. Experimental sleep deprivation has demonstrated the role of sleep in adult neurobehavioral function (Minkel, Htaik, Banks, & Dinges, 2011; Van Dongen, Maislin, Mullington, & Dinges, 2003; Walker, 2008), but fewer experimental studies have been conducted with children (Fallone et al., 2005; Randazzo, Muehlbach, Schweitzer, & Walsh, 1998; Sadeh et al., 2003). Only a few published experimental sleep studies have included children younger than 7-year-olds (Berger et al., 2012; J. C. Lam et al., 2011; Miller et al., 2015) and most of these studies have manipulated daytime sleep through nap deprivation.

Experimental sleep deprivation relies on accurate sleep measurement. Polysomnography is the gold standard sleep measurement, but consumes considerable time and expense. Videosomnography has been used successfully to measure young children's sleep (Gaylor, Goodlin-Jones, & Anders, 2001; Sitnick, Goodlin-Jones, & Anders, 2008), but is expensive and time-consuming like polysomnography. In contrast, actigraph motion monitoring of child sleep provides a less intrusive measure that is easy to administer in a child's home sleeping environment, and can be efficiently scored (Bélanger, Simard, Bernier, & Carrier, 2014; Sadeh, Lavie, Scher, Tirosh, & Epstein,



1991). The availability of actigraphy makes objective measurement of sleep and experimental sleep restriction with children more feasible (Acebo & Sadeh, 1999; Sadeh et al., 1991) as a less intrusive method than polysomnography for sleep measurement. In the current study, an actigraph-monitored sleep restriction protocol was designed for families to follow at home with typically-developing preschool children. Participation in a home-based protocol necessarily involves the child's main caregivers, who play a major role in maintaining consistent bedtime and waking schedules in this age group. The standard length of a child and youth experimental sleep study with actigraph sleep measurement is often two weeks or more (Fallone et al., 2002; Sadeh et al., 2003; Vriend et al., 2013). Unlike school-aged children and adolescents who have successfully participated in experimental sleep research, parents and young children may face different challenges following a research-imposed sleep schedule over the course of a study.

### **3.2 Child and Family Characteristics Relevant to Sleep Measurement**

Concurrent measurement of child characteristics along with experimental sleep manipulation could help to identify any characteristics of young children that interfere with participating in an experimental protocol. In particular, children who have more difficulty calmly following adult directions, or with regulating their emotions, may have more difficulty complying with an experimental protocol. As a group, young children are more likely to become upset or to react intensely in challenging situations as a developmental consequence of having reduced internal regulatory abilities compared with school-aged children (Cole et al., 2011; Kopp, 1989; Potegal & Davidson, 2003). Children who have more trouble regulating their negative feelings may have difficulty

adhering to a home-based protocol if parents are more cautious about provoking negative child reactions (Cole, LeDonne, & Tan, 2013). As a result, parents may hesitate to enforce changes required for a voluntarily undertaken experimental protocol. If child characteristics make it less likely for them follow a sleep restriction protocol, it could inform future experimental studies that vary young children's sleep schedules.

Determining whether parent-perceived child characteristics are related to successful implementation of experimental sleep restrictions is essential to sleep measurement in this age group. Therefore, this pilot study provides essential information for pediatric sleep researchers to conduct sleep restriction studies that are best suited to the developmental needs of preschool children.

The goal of this study was to provide empirical data on the feasibility of experimental sleep restriction with younger children, and recommendations for researchers who hope to undertake similar studies. Given the number of factors that could potentially affect young children's adherence to an experimental sleep restriction protocol, our goal for the current study was to examine the ability of 3- to 5-year-old children and their parents to adhere to experimental sleep restriction requirements at home. We also planned to explore predictors of adherence to the protocol. Children who had greater parent-reported behavioral issues and greater parent-reported emotional regulation difficulties were expected to be less likely to adhere to the experimental protocol. The descriptive statistics of how children slept before and after the planned experimental manipulations are reported to illustrate the degree of adherence to the experimental protocol and how it differed from children's sleep before changes were prescribed.

### 3.3 Method

#### 3.3.1 Participants

Parents living in a mid-sized city and surrounding communities in Ontario, Canada were recruited to participate in the study with their 3- to 5-year-old children. Recruitment was conducted through advertisements in online and print media, and through distribution of flyers at community agencies serving parents with young children; a telephone number and email address were provided through which families were invited to contact the research team. Past parent participants who had volunteered for child developmental research and had agreed to be contacted again for future studies were also contacted for screening. Research assistants also visited community agencies and daycare centres in person to share study information with parents and collected contact information from parents who expressed interest in participating. Parents were eligible to be screened for participation if: (a) they and their child could speak English, (b) the parent could be contacted by telephone, and (c) if their child was at least three years of age but had not yet reached his or her sixth birthday. The Human Subjects Research Ethics Board at the authors' academic institution approved all procedures for recruitment, screening and data collection.

- ii) **Screening.** Telephone screening interviews were conducted with parents to explain the requirements of the study and determine whether their child was eligible for the study. Appendix A illustrates the number parents contacted from screening recruitment to completion of the experiment. Only one child per family was invited to participate in the study. Participants were scheduled as soon as practical for the family after the screening process. Testing

occurred throughout the year and season of participation (spring, summer, fall, or winter) and was coded based on the month that the child started the study: three consecutive months were designated for each season (Table 3.1). Child age was also calculated from the day that they began the study ( $M = 4.3$  years,  $SD = .88$ ). A summary of demographic characteristics of participants is presented in Table 3.1.

**Exclusion Criteria.** Children were excluded if parents' reported: a) that their child snored regularly during sleep (i.e., a potential indication of sleep disordered breathing), b) that their child had been diagnosed with a developmental (e.g., Autism Spectrum Disorder), behavioral (e.g., Attention-Deficit/Hyperactivity Disorder), or health condition (e.g., asthma) that disrupted the child's sleep or required care during the night, or c) if the child did not live with the parent full time. These exclusion criteria were chosen so that the study would involve only children whose sleep quantity and quality would not be disturbed by pre-existing conditions. Criterion (c) was chosen to minimize potential disruptions to home sleeping environments during the time of the study. Children were also excluded if parents reported child co-sleeping, bedtime resistance, or night waking, defined as delaying bedtime or waking at night at least twice per week, with episodes lasting at least 20 minutes on average within the month prior to the study (Anders & Dahl, 2007).

### Table 3.1

*Child Parent and Family Demographic Characteristics of Full Sample (N = 69)*

Child	<i>n</i> (%)
Age	

3.0-3.9 years	30 (43%)
4.0-4.9 years	23 (33%)
5.0-5.9 years	16 (23%)
Season of participation	
Spring (March –May)	21 (30%)
Summer (June–August)	16 (23%)
Fall (September–November)	26 (38%)
Winter (December–February)	6 (9%)
<b>Parent</b>	
Marital Status	
Single	5 (7%)
Divorced/Separated	1 (1%)
Common-Law	5 (7%)
Married	58 (85%)
Highest Education (Primary parent participant)	
Some secondary school	2 (3%)
Complete secondary school	4 (6%)
Some postsecondary school	12 (17%)
Complete Diploma/College/Trade	15 (22%)
Complete Bachelor’s Degree	28 (41%)
Complete Master’s/ Doctoral Degree	5 (7%)
Complete Professional Degree (e.g. Law)	3 (4%)
<b>Family</b>	
Children at home	
One	12 (17%)
Two	31 (45%)
Three	19 (28%)
Four or more	7 (10%)
Annual Household Income	
under \$20 000	7 (10%)
\$20 000 - \$39 999	9 (13%)
\$40 000 - \$59 999	8 (12%)
\$60 000 - \$79 999	13 (19%)
\$80 000 - \$99 999	13 (19%)
\$100 000 and over	17 (25%)
Prefer not to respond	1 (1%)
Language Spoken at home	
English	66 (96%)
Other (Arabic, Mandarin Chinese)	3 (4%)

### 3.3.2 Measures

**Sleep: Actigraphy.** Child sleep was measured using the Ambulatory Monitoring MicroMini Motionlogger actigraph units (Ambulatory Monitoring Inc., 2010).

Actigraphs are worn on the body and measure sleep through motion recording to provide

a measure of sleep and wake states. Actigraphs have been used extensively in child sleep research to measure nocturnal sleep onset, duration and timing of nocturnal awakenings, and morning awakening; from these variables sleep duration and sleep efficiency can be calculated (Acebo & Sadeh, 1999; Acebo et al., 2005; Epstein, Herer, Tzischinsky, & Lavie, 1997; Fallone et al., 2002; Tikotzky & Sadeh, 2001). Actigraph measurement of sleep in children age 1 to 4 years has been validated against polysomnography, the gold standard for sleep measurement (Bélanger, Bernier, Paquet, Simard, & Carrier, 2013; Bélanger et al., 2014; Sadeh et al., 1991).

The Zero-Crossing Mode (ZCM) was used for data collection and measures activity in 1 minute epochs through a 24-hour period. Actigraph units were initialized for data collection using the *ActMillenium* 4.0 software program (Ambulatory Monitoring, 2010), and data were downloaded from devices using the same program. Raw activity data was automatically scored based on 1-minute epochs using the validated ASA algorithm (Sadeh et al., 1991) in the *Action4* 1.1 software program (Ambulatory Monitoring, 2010). This automatic scoring was compared with parent sleep diaries to confirm the timing of sleep periods (i.e., bedtime, rise time, naps). Sleep minutes scored from actigraph were counted when they occurred within 30 minutes before the parent diary entry of sleep start time, and 30 minutes after the child woke for the morning (Acebo & Sadeh, 1999; Acebo et al., 2005; Sadeh et al., 1991). Children were asked to wear the actigraphs at all times during the study to allow for recording of daytime napping, still common among children of the ages recruited. Children were permitted to wear the actigraph on their ankle instead of their wrist if they found this easier to tolerate; 10 children who completed the study chose this option. Previous research has shown no

difference between actigraph sleep data recorded using ankle versus wrist monitoring in young children (Bélanger et al., 2013).

**Sleep: Parent Diary.** Parents used a structured diary to record their children's sleep each day. In the diary, parents completed fields specifying the time their child went to bed (i.e., when the lights were turned off so the child could initiate sleep), the time their child actually went to sleep, the duration of any waking during the night before morning awakening, and the time the child woke for the day the following morning. Parents also reported the beginning and end of their child's daytime nap each day, if applicable. Additional space was left blank on each diary day for parents to record any unusual positive (e.g., special visit) or negative (e.g., illness) events for their child or family on each day during the study. Caregiver sleep diaries are required to ensure that actigraph motion and sleep data are coded correctly (Acebo et al., 2005; Sadeh, 2008), as data may erroneously be scored as sleep when an actigraph is removed if diary reports of sleep start and end times are not provided. Sleep diaries have been used in several pediatric sleep studies and have been shown to agree with actigraph measurement of sleep onset and sleep end times (95% of scores are within 30 minutes of an objective measure of sleep onset and sleep end time) (Werner, Molinari, Guyer, & Jenni, 2008). The diary for the current study was adapted from one developed by Corkum and colleagues (Corkum, Tannock, Moldofsky, Hogg-Johnson, & Humphries, 2001; Vriend, Davidson, Shaffner, Corkum, & Rusak).

**Behavior Problems: Strengths and Difficulties Questionnaire.** The Strengths and Difficulties Questionnaire (SDQ) is a 25-item parent-report measure of child behavior and can effectively discriminate between children with and without clinically

significant psychiatric disorders (Goodman, Ford, Simmons, Gatward, & Meltzer, 2000; Goodman & Scott, 1999). The SDQ includes four scales measuring potential problem behavior: 1) Emotional Symptoms (e.g., *Many fears, easily scared*); 2) Conduct Problems (e.g., *Often fights with other children or bullies them*); 3) Hyperactivity (e.g., *Restless, overactive, cannot stay still for long*); and 4) Peer Problems (e.g., *Rather solitary, tends to play alone*). A fifth scale measures Prosocial behavior (e.g., *Often volunteers to help others*) and is not scored with problems. Parents rate the statements on a 3-point Likert scale according to how true they are for the child (0 = *Not True*, 1 = *Somewhat True*, 2 = *Certainly True*). The scores of the four problems scales are added together to form a Total Difficulties score that can range from 0 to 40. A parent-reported Total Difficulties score of 17 or greater indicates that the child may have a psychiatric diagnosis, although the authors note that these norms can vary between cohorts of children (Goodman, Ford, Simmons, et al., 2000). Internal consistency for the parent report SDQ was good in a large low-risk community sample of children and youth, with Cronbach  $\alpha = .82$ , (Goodman, 2001). The SDQ also has very good specificity (94%) and negative predictive power (96%) for the Total Difficulties score as a predictor of DSM-IV diagnosis (Goodman, 2001) rated from structured interviews and questionnaires (Goodman, Ford, Richards, Gatward, & Meltzer, 2000).

**Emotion Regulation: Emotion Questionnaire.** The Emotion Questionnaire (EQ) (Rydell, Berlin, & Bohlin, 2003; Rydell, Thorell, & Bohlin, 2004) is a 40-item parent-report measure of child emotionality and emotion regulation in response to 12 common situations where children may experience positive or negative emotions. Parents rate three to four statements relating to each situation on a 5-point Likert scale (1 = *doesn't*



*apply at all; 5= applies very well*). The statements reflect either the intensity of a child's emotional response to a situation (e.g., *When my child gets into a conflict with a peer, he/she reacts strongly and intensely*), or the child's ability to recover from the emotional situation (e.g., *My child has difficulties calming down on his/her own*). The EQ items measure four different domains: 1) Negative Emotionality, 2) Positive Emotionality, 3) Regulation of Negative Emotions, and 4) Regulation of Positive Emotions. Within the Negative Emotionality and Regulation of Negative Emotions scale, there are items relating to anger, fear, and sadness. An overall score of Emotion Regulation can also be calculated using all items from both Regulation scales.

The Emotion Questionnaire has been validated with a sample of 5- and 6-year-old children (Rydell et al., 2003). The internal consistency of the positive and negative emotionality subscales was adequate in the standardization sample ( $\alpha = .65 - .77$ ), as was the internal consistency of the regulation subscales ( $\alpha = .69 - .79$ ). The Emotionality subscales ( $r = .62 - .78$ ) and Emotion Regulation subscales ( $r = .74 - .79$ ) both showed reasonable test-retest reliability when completed twice after a 5 week period (Rydell et al., 2003). The Emotion Questionnaire has also been used in previous research with 3- to 5-year-old children (Giesbrecht, 2008). Parent-report data for items on the EQ used in this age range yielded good internal consistency for overall anger and sadness regulation ( $\alpha = .86$ ) and overall anger and sadness emotionality ( $\alpha = .80$ ). In addition, the regulation items were correlated with child-reported coping with emotional situations (children reported their responses to situations with pictures of vignettes;  $r = .18, p < .05$ ) and parent-report children's emotional coping ( $r = .35, p < .001$ ), supporting the construct

validity of the Emotion Questionnaire as a measure of younger children's emotional regulation abilities (Giesbrecht, 2008).

**Demographics.** Eligible parents answered questions about their family in the initial telephone screening interview. The parent completing the interview reported their current marital status, the number of children living in the household (including the target child who would participate in the study), the language most often spoken in the family home and their total annual household income. Parents were also asked to report the highest level of formal education they had completed (e.g., high school, trade school, completion of college degree). Parents who reported that they were married or living in a common-law partnership were also asked to report their partner's highest level of formal education.

### 3.3.3 Procedure

Parents who were willing to participate and met appropriate inclusion/exclusion criteria arranged a home visit with a member of the research team. At the first home visit, the researcher met with the parent who would be primarily responsible for keeping the sleep diary during the study and filling out the questionnaires; i.e., the parent who was usually responsible for organizing the child's bedtime and rising routines. The requirements and details of the study that had been described in the telephone interview were reviewed again, and the parent provided informed consent on behalf of her/himself and her/his participating child. Parents were asked to complete the child questionnaires during the first few days of the study and to complete the sleep diary each day indicating when the child was asleep and awake, as well as when the actigraph was removed during the week. The researcher also confirmed the child's usual bedtime and waking time and

asked the parent to keep this as consistent as possible during the first seven days of the study (the baseline phase). On a day pre-arranged to accommodate the parent's schedule, a research assistant not involved in the child testing telephoned the parent to confirm that the child was wearing the actigraphs consistently and sleeping regularly, and that the parent was remembering to keep the sleep diary. The research assistant then told the parent which of the four sleep groups her/his child would participate in during the last three days of the study and gave instructions about how to adjust the child's sleep based on the parent report of the child's sleeping and waking during baseline.

Participants were randomly assigned to one of four experimental sleep groups, with randomization stratified by the child's age in years in order to maintain equivalent age distribution in each experimental group. The required sleep changes in each group took place in the last three nights of the study (Days 8, 9, and 10). Children in Group 1 (Control) were to maintain their regular sleep schedule. Children in Group 2 (Sleep Restriction A) were to go to bed 20 minutes later than their usual bedtime and wake at their usual time each morning. Children in Group 3 (Sleep Restriction B) were to go to bed 40 minutes later than their usual bedtime and wake at the usual time each morning, resulting in sleep restriction. Finally, children in Group 4 (Sleep Fragmentation) were to maintain their usual bedtime and wake time, but were awoken for 20 minutes during the night, resulting in sleep fragmentation. Parents were asked to wake their children approximately one hour and 15 minutes after their child had fallen asleep, based on normative data suggesting that 3- to 5-year-old children would be less likely to be in deep NREM sleep at this point and easier to wake (Scholle et al., 2011). Parents in the sleep fragmentation condition were given an additional activity in which children would have

to find a hidden stuffed animal and put it back to bed during their time awake. Researchers provided the toys and instructions for this activity, but parents were encouraged to try other activities to keep their child awake for the required 20 minutes. The parameters for the sleep restriction-fragmentation protocol were developed based on a previous study (see Chapter 2) using a participatory design approach (Spinuzzi, 2005).

After the night of Day 10, the research assistant collected the actigraph and sleep diary from the family at a final home visit, and obtained feedback from the participating parents on their experience of the study. At this visit, the child completed a neurobehavioral assessment, the results of which are reported later in this dissertation (see Chapter 4).

**Protocol Adherence:** Some variation in the degree of sleep restriction achieved among children within each condition was expected; therefore, we developed a-priori definitions of adherence to experimentally-assigned sleep restriction. A summary of the procedural requirements and the definitions of adherence for each condition are presented in Table 3.2. Adherence criteria were chosen to allow for some degree of variability in meeting the target sleep restriction, but to maximize the possibility of mean differences in sleep restriction in the experimental phase compared to baseline between groups. For all conditions, parents were asked to follow the assigned procedure for three nights (beginning on Day 8 of the study) and to continue to ensure that the child followed his/her regular waking time and daytime napping schedule during the final three days of the study.

**Table 3.2**

*The Procedural Requirements for Each Experimental Sleep Condition and the Corresponding Definitions for Adherence to Assigned Condition According to Actigraph-Measured Sleep*

Condition Name	Procedure	Definition of 75% Adherence
1) Control	No changes to bedtime	Slept not more than 10 minutes less on average in experimental phase vs baseline
2) Sleep Restriction 20 minutes	Bedtime 20 minutes later than baseline	Slept at least 15 minutes less on average in experimental phase vs baseline
3) Sleep Restriction 40 minutes	Bedtime 40 minutes later than baseline	Slept at least 30 minutes less on average in experimental phase vs baseline
4) Sleep Fragmentation	No changes to bedtime; wake 75-90 minutes after falling asleep; remain awake for 20 minutes before returning to sleep	Slept at least 15 minutes less on average in experimental phase vs baseline, and awake for at least 15 minutes during night time sleep period

### 3.3.4 Data Analysis

For children who napped during the study, daytime sleep minutes were added to night time sleep when calculating sleep during the baseline and experimental study phases. Unless otherwise indicated, children's total sleep times are reported including naptime on the previous day in addition to night time sleep; the terms night time sleep and naps are used where these are considered separately.

A chi-square analysis was used to compare percentage adherence within each assigned condition to determine whether adherence was related to group assignment, to illustrate whether any assigned condition was inherently more difficult. We used a logistic regression to check whether adherence to the imposed sleep schedule was systematically related to measured child and family characteristics. Family characteristics included parental marital status, parent education, family income, and number of children in the family. Child characteristics included age and sex, emotional regulation ability from the Emotion Questionnaire (EQ), and behavior problems from the Strengths and Difficulties Questionnaire (SDQ).

A logistic regression was conducted using parent education and family income, as well as parent-reported child behavior problems, and child emotional regulation as predictors of adherence versus non-adherence (see Table 3.2 for a priori definitions). Child behavior problems from the SDQ and child emotion regulation difficulties from the EQ were entered as continuous variables. The education of the primary participating parent was entered as a dichotomous variable dividing the sample into lower (incomplete high school to completed college certification) and higher education (completed undergraduate university program to professional or doctoral qualification). Income was

divided into two groups representing a median split between lower and higher income groups reported in the sample.

**Individual Sleep Restriction:** Additional descriptive statistics were calculated to illustrate the differences between how children slept during the experimental phase compared to baseline. The standard deviation of sleep between nights for individual participants in different group, as well as the standard deviations between the four groups were calculated and the sleep variability in different phases of the experiment (i.e., baseline and experimental phases) were compared to determine whether there was notable deviation in sleep between each phase. The comparison helped to determine whether the amount of sleep children obtained on experimental days was different from the typical variability in amount of sleep reported during the baseline week when parents were asked not to change sleep.

### 3.4 Results

#### 3.4.1 Data Screening and Exclusion

One child who completed the experimental condition was excluded due to a parent-reported history of child head injury with loss of consciousness identified after screening, resulting in an overall sample of 69 participants who completed the protocol (see Table 3.1). Technical failure resulted in missing actigraph records for  $n = 15$  child participants, leaving  $n = 54$  participants (27 boys) who had available actigraph sleep data. Some children were reported to have fallen asleep in a car or stroller ( $n = 8$ ), or to have been ill/ require medication at some point during the study ( $n = 20$ ). These events affected 25 children in the overall sample, and the days when these events occurred were dropped from analysis (Acebo et al., 2005; Bélanger et al., 2014).

### 3.4.2 Preliminary Analyses

In general, reliability of actigraphy-measured sleep parameters increases across the number of nights of measurement, and is most reliable as an overall measure of night time sleep in children between 3 and 5 years of age when at least 5 nights of data are used (Acebo & Sadeh, 1999). Actigraph measurement is less reliable overall in its estimation of night awakenings, as restless movement during sleep can be scored as night waking, and quiet wakefulness can be scored as sleep (Acebo & Sadeh, 1999; Bélanger et al., 2013; Goodlin-Jones, Tang, Liu, & Anders, 2008; Sitnick et al., 2008). However, night waking was considered to have occurred for participants who experienced 3 or more consecutive minutes of time awake based on actigraph readings – as defined in the “smoothing routine” – to reduce the likelihood of brief movements in sleep being coded as night waking (Acebo et al., 2005). To describe the general baseline characteristics of sleep in the sample, we used all nights available for each participant. Most children ( $n = 35$ ) had actigraph data for all 7 days of the baseline; one child had a minimum 3 days; three children had 4 days, two children had 5 days, and 23% had 6 days of data. Children’s average sleep for each night was calculated as the actigraph measured night waking minutes subtracted from the sleep period, with actigraph-measured daytime sleep added. The sleep data used for analysis was based on actigraphy, except for the comparison of the diary records to actigraph records for the purposes of illustration, reported below.

### 3.4.3 Comparison of Actigraph and Diary Records of Sleep

Comparison of actigraph and diary measures of sleep is not a comparison of independent measures, as the diary guides the scoring of actigraph data, and sleep is only



scored within diary-confirmed sleep periods. With this in mind, a comparison of parent diary report and actigraph-recorded sleep parameters was performed to determine how parent records of sleep corresponded to actigraph-recorded sleep in the current study. Total sleep time based on diary versus actigraph record was significantly correlated during the baseline experimental phase  $r(51) = .66, p < .001$ , and during the experimental phase,  $r(51) = .62, p < .001$ . Parent diary reports of night waking were also related to actigraph measures of night waking in the experimental phase,  $r(51) = .41, p = .001$ . However, parent diary estimates of night waking were not significantly related to actigraph night waking in the baseline phase,  $r(51) = .09, p = .25$ . Paired-sample t-tests showed that parents recorded that their child slept longer on baseline nights  $t(53) = -9.8, p < .001$ , as well as on experiment nights  $t(52) = -8.00, p < .001$  compared to actigraph recordings. Parents also recorded fewer night waking minutes than measured by actigraphy on baseline  $t(53) = 7.9, p < .001$ , and experiment  $t(52) = 7.17, p < .001$  days.

#### 3.4.4 **Baseline and Experimental Sleep Characteristics**

Table 3.3 summarizes the baseline sleep schedules for study participants from actigraph and sleep diary measurement. The average time spent asleep at night during the baseline was 10.0 hours ( $SD = 0.70$ ) according to actigraphy and 10.6 hours ( $SD = 0.56$ ) according to parent diary. Forty children (58%) napped on at least one day during the baseline phase of study; for these children average nap time was 0.38 hours ( $SD = 0.22$ ) in the sleep diary and 0.43 hours ( $SD = 0.22$ ) by actigraphy.

The season (i.e., summer – June-August; fall – September-November; winter – December-February; spring – March-May) of participation was not related to baseline sleep time  $F(3,49) = 1.05, p = .38$ , or to night waking minutes,  $F(3,49) = 0.82, p = .49$ . A

paired sample t-test compared mean sleep on weekdays (Sunday to Thursday:  $M = 10.0$ ,  $SD = 0.7$ ) to mean sleep on weekends (Friday and Saturday). This difference was not significant  $t(48) = 0.62$ ,  $p = .54$ . Participant age in years was not related to night waking minutes,  $F(2,50) = .61$ ,  $p = .55$ , or total sleep time,  $F(2,50) = .24$ ,  $p = .79$ , during baseline. Boys and girls did not differ in total sleep time,  $t(51) = -.12$ ,  $p = .90$ , or night waking,  $t(51) = .20$ ,  $p = .84$ .

**Table 3.3**

*Characteristics of Participant Sleep Schedules over 7 day Baseline Study Phase*

Sleep Parameter	Actigraph ( $n=54$ ) Mean (SD)	Parent Diary ( $n=69$ ) Mean (SD)
Number of Nights for Calculation	6.4 (.96)	6.9 (.27)
Average Nighttime Sleep Onset (24 hour clock)	20:34 (:41)	20:31 (:38)
Average Morning Waking (24 hour clock)	07:04 (:29)	7:14 (:29)
Average Night Waking		
Hours	0.5 (0.45)	0.05 (0.07)
Minutes	32 (27)	3 (4)
Average Night Time Sleep		
Hours	10.0 (0.70)	10.6 (.56)
Minutes	598 (42)	640 (34)
Daytime Sleep	$(n = 21)^+$	$(n = 29)$

Number of Days Napped		
1	10	11
2	2	6
3	1	2
4	3	2
5	2	5
6	3	2
7	-	1
Average Total Naptime Sleep		
Hours	0.43 (0.22)	0.38 (0.22)
Minutes	26 (12)	23 (13)
Daily Sleep Variability		
Average Within-Subject SD of Total Sleep		
Hours	0.71 (0.37)	0.53 (0.22)
Minutes	43 (22)	32 (13)

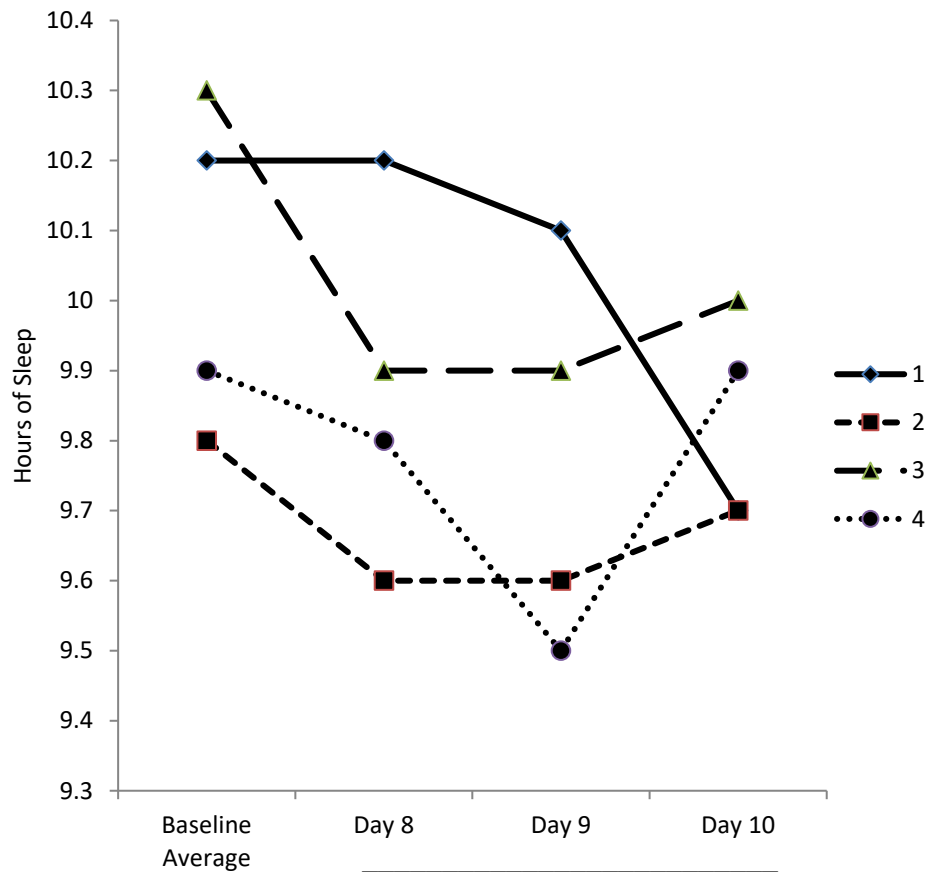
\*Of the total sample  $n=40$  did not nap on any day during baseline.

+Due to missing data only 21 participants had naps recorded on actigraphs.

### 3.4.5 Sleep Protocol Adherence

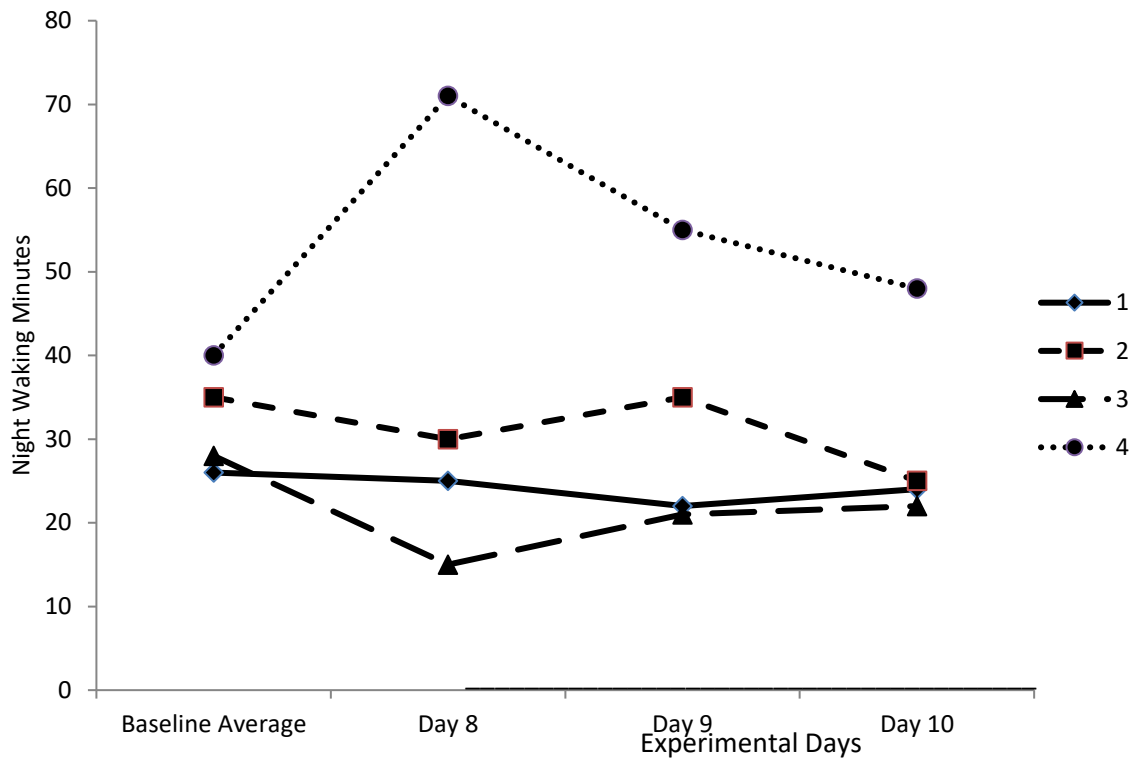
We used ANOVAs to test: (a) whether baseline sleep differed between groups, (b) whether differences between experimental-phase sleep and baseline-phase sleep differed between groups, and (c) whether night waking differed between groups. ANOVAs revealed no differences in groups for baseline total sleep duration,  $F(3, 49) = 1.58$ ,  $p = .21$ . The overall difference in sleep time between baseline and experimental conditions was also not significant,  $F(3, 49) = .25$ ,  $p = .86$ ; see Figure 3.1. A 2 within (baseline; experimental phase) x 4 between (experimental group) ANOVA confirmed that only

participants in Group 4 (sleep fragmentation) were awake more at night in the experimental phase compared with baseline phase [group x night of study interaction  $F(3, 49) = 3.00, p = .04$ ]; none of the other groups' time awake during the night differed between baseline and experimental phases [ $F(1, 49) = .01, p = .91$ ; see Figure 3.2].



**Figure 3.1**

Overall total sleep hours for participants at baseline, and during Day 8, 9, and 10. Experimental Group. 1 = Control Group; 2 = Sleep Restriction, 20 minutes; 3 = Sleep Restriction, 30 minutes; 4 = Sleep Fragmentation



**Figure 3.2**

Night waking minutes for participants at baseline, and during Days 8, 9, and 10. Experimental Group (1 = Control Group; 2 = Sleep Restriction, 20 minutes; 3 = Sleep Restriction, 30 minutes; 4 = Sleep Fragmentation).

Using the definitions outlined in Table 3.2, we compared children's sleep during the baseline phase to sleep during the experimental phase. Across groups, over half of the participants (55%;  $n = 29$ ) did not meet the adherence criteria for their assigned condition, based on average total sleep differences between baseline and experimental phases of the study. The likelihood of meeting adherence criteria did not vary according to assigned condition  $\chi^2(4, N = 53) = .71, p = .47$ .

To examine further how children in different groups slept in the experimental phase compared to the baseline phase of the study, we assessed the degree to which children in each group extended, restricted, or did not differ, in their sleep from their mean sleep in the baseline phase. Five categories were formed to summarize these variables across groups. (1) No change in child sleep was defined as average experimental phase sleep within  $\pm 5$  minutes of baseline phase sleep. (2) Sleeping over 5 minutes longer than baseline was considered sleep extension. Sleep restriction was divided into three categories: (3) 5 to 20 minutes less sleep than baseline, (4) 21 to 40 minutes sleep less than baseline and (5) greater than 40 minutes less sleep than baseline. The number and percentage of participants who met criteria for the different sleep categories within each group are presented in Table 3.4.

**Table 3.4**

*Number and Percentage of Participants from Each Experimental Condition Experiencing Different Amounts of Sleep Restriction or Extension in Experiment Compared to Baseline based on Actigraph Sleep Measurement.*

Sleep Category	Experimental Group			
	Control	Sleep Restriction 20 minutes	Sleep Restriction 40 minutes	Sleep Fragmentation
	( <i>n</i> = 14)	( <i>n</i> = 12)	( <i>n</i> = 15)	( <i>n</i> = 12)
	% ( <i>n</i> )	% ( <i>n</i> )	% ( <i>n</i> )	% ( <i>n</i> )
a) No change from baseline 0 +/- 5 minutes	14 (2)	0	20 (3)	25 (3)
b) Sleep Extension	36 (5)	33 (4)	13 (2)	17 (2)

> 5 minutes				
c) Sleep Restriction	21 (3)	25 (3)	20 (3)	17 (2)
5-20 minutes				
d) Sleep Restriction	21 (3)	25 (3)	13 (2)	25 (3)
21-40 minutes				
e) Sleep Restriction	7 (1)	17 (2)	33 (5)	17 (2)
> 40 minutes				
Mean (SD) Minutes of Sleep Restriction between Baseline and Experimental Condition	11.0 (36.4)	10.7 (43.1)	19.7 (25.0)	11.6 (23.7)

Note: Percentages may not add to 100 due to rounding.

**Predicting Adherence to the Experimental Condition.** The logistic regression used experimental adherence as an outcome variable, with parent education, parent income, child behavior problems and child emotion regulation difficulties as predictors. Prior to running the logistic regression, we determined that there were no pre-existing between-group differences in parent education,  $\chi^2(4, N = 53) = 1.67, p = .64$ ; parent income,  $\chi^2(4, N = 52) = 5.79, p = .45$ ; overall child behavior problems,  $F(3, 49) = 1.48, p = .23$ ; or emotion regulation ability  $F(3, 41) = .02, p = .99$  (see Table 3.5). Before running the logistic regression model, missing emotion regulation scores ( $n=8$  due to early study participants not having received the questionnaire) were replaced using the mean emotion regulation score from the child's age group (i.e., age 3, 4 or 5 years).

**Table 3.5**

*Parent Reported Child and Family Characteristics by Assigned Sleep Group*

	Control <i>n</i> =14	Sleep Restriction 20 minutes <i>n</i> =12	Sleep Restriction 40 minutes <i>n</i> =15	Sleep Fragmentation <i>n</i> =12
	% ( <i>n</i> )	% ( <i>n</i> )	% ( <i>n</i> )	% ( <i>n</i> )
Parent Education				
-Bachelors level or higher	57 (8)	50 (6)	53 (8)	33 (4)
Family Income				
- Greater than \$80 000 per year	24 (6)	32 (8)	20 (5)	24 (6)
	M(SD)	M(SD)	M(SD)	M(SD)
Total Child Behavior Problems				
Mean (SD)	6.8 (4.4)	7.8 (4.4)	5.9 (4.1)	9.8 (6.6)
Child Emotion Regulation Abilities				
Mean (SD)	3.8 (.69)	3.9 (.59)	3.8 (.52)	3.8 (.59)

A test of the model with all four predictors compared to the constant-only model was not significant,  $\chi^2(4, N = 52) = 1.5, p = .83$  (Table 3.6). Parent education and parent income groups overlapped significantly [ $\chi^2(2, N = 52) = 4.9, p = .03$ ], therefore the logistic regression was run again without family income included as a predictor. The model with three predictors was also not significant:  $\chi^2(3, N = 53) = 1.29, p = .73$ . None of the outcome variables in the model predicted adherence or non-adherence in the experiment (Table 3.6). Given that there was large variation in sleep durations across nights within subjects in the baseline period, we examined whether children who did not achieve adherence criteria had greater degrees of variability (i.e., larger SD in sleep duration) in their sleep at baseline. There was no difference in overall variation from mean sleep time between the children who met 75% adherence criteria for their condition and children who did not do so,  $t(51) = -.34, p = .73$ .



**Table 3.6***Logistic Regression Examining Child and Family Predictors of Experimental Adherence*

Entered Variables	95% Confidence Interval				
	O.R.	<i>b</i>	Lower Bound	Upper Bound	<i>p</i>
Parent Education	.67	-.66	.21	2.2	0.51
Family Income	1.40	.53	.40	4.9	0.60
Total Child Behavior Problems	1.01	.17	.19	1.67	0.86
Child Emotion Regulation Abilities	.57	-1.03	.91	1.13	0.30

O.R. = Odds Ratio

*b* = beta weight

### 3.4.6 Individual Sleep Restriction

The standard deviation of daily sleep *within* participants was quite large; at baseline SD = 43 minutes overall, based on actigraphy (see Table 3.3). There was also wide variation *between* participants' measured sleep restriction in each assigned sleep group; SD for each group was between 24 and 43 minutes (Table 3.4) Given this variability, we tested whether each child's sleep was restricted in the experiment more than their typical individual sleep variability in the baseline phase. We calculated a baseline sleep standard deviation for all participants and compared whether their sleep restriction amounted to at least 1.5 standard deviations less than their mean baseline sleep. Based on this calculation, two children were sleep restricted on at least two of the three experimental days according to actigraphy and nine children were sleep restricted according to parent sleep diaries. Given that actigraphy records showed that only 2 children were sleep restricted compared to their usual baseline sleep, the number was considered too small to run an analysis of predictors that would provide informative results.

### 3.5 Discussion

This experimental study represents the first overnight experimental sleep restriction protocol with preschool-aged children. The primary goal was to conduct a home-based sleep restriction protocol with 3- to 5-year-old children in order to identify characteristics that could inform future sleep research examining the impact of sleep restriction on child functioning. We expected that some family and child characteristics would be related to difficulties implementing the sleep restriction protocol, but there was no relation between children's reported behavior problems, emotion regulation abilities and experimental adherence. Similarly, the family characteristics of household income and parental education did not relate to experimental adherence, suggesting these factors did not systematically make it more difficult for parents to implement the procedure with their children at home.

#### 3.5.1 Individual Sleep Variability and Sleep Restriction

During the study, a significant challenge in implementing the experimental protocol that emerged after the study was completed was the variability in child sleep schedules during baseline (see Table 3.3). Some parents reported anecdotally that, while they considered their children to be good and regular sleepers, they felt it was difficult to have their child go to bed and to wake up within 5-10 minutes of a set time on each day of the study. A few children demonstrated baseline differences from their average sleep time that were greater than one hour, while most children's baseline sleep variability was closer to a half an hour. This is a noteworthy characteristic of sleep in this group of young children. Previous studies have identified the mean squared deviation of variability in parent diary-recorded sleep times as a predictor of poorer preschool-teacher reported

adjustment (Bates et al., 2002). Bates and colleagues observed greater within-child variability in their sample of low-income children, and these children were older on average compared with the current participants. This suggests that variability in sleep may have a greater impact on adjustment and behaviour in older children. Other research that reports an association between variability in sleep times has relied on parent responses to general questions about whether their child goes to bed at a regular time (Kelly et al., 2013). The children in our study did not experience poor adjustment, based on parents' reports of child behavior problems and emotion regulation in questionnaires. Therefore, preschoolers may be resilient to sleep variability of up to 45 minutes. This is one of the few studies to document normal sleep patterns among healthy preschool-age children. Future research must clarify the degree of sleep variability in the early years that is normal and the degree that impacts child adjustment in the 3- to 5-year-old age range.

There was no evidence in our sample of an association between sleep time variability and poorer daytime functioning, contrasting with previous research (Bates et al., 2002; Kelly et al., 2013). The current protocol used actigraphy to measure sleep which measures different aspects of sleep than parent diary report (Bélanger et al., 2014; Sitnick et al., 2008). Though parent report is known to be highly related to actigraphy measures such as bedtimes, wake times, and overall sleep times (Acebo & Sadeh, 1999; Acebo et al., 2005; Sadeh et al., 1991), it can overestimate sleep time compared with actigraphy, given that parents often fail to report periods of night waking that are common in early childhood (Sitnick et al., 2008). Conversely, actigraphy can underestimate the amount of time asleep, as young children may be more restless sleepers

than adults and actigraphy can record such motion as wakefulness (Bélanger et al., 2013; Bélanger et al., 2014). However, as both actigraphy and sleep diaries provide daily reports of child sleeping and waking, they probably reflect a clearer picture of the natural variability that occurs in children's sleep among families who report no ongoing problems in this area during preschool. Given the relative paucity of published empirical data on sleep in typical 3- to 5-year-old children, this preliminary information on sleep is essential to understanding ongoing child development.

### 3.5.2 Protocol Adherence

Over half of child participants did not meet our adherence criteria. One feature of experimental adherence that was objectively successful was the requirement that parents wake children assigned to the sleep fragmentation condition: there was a significant difference between average minutes awake at night in the sleep fragmentation groups compared to other sleep groups in the experiment. However, only 45% of the children in this group met the criteria for adherence, a minimum reduction in sleep over the 3 days of the experiment condition compared to baseline (i.e., at least 15 minutes on average for this study). Two families voluntarily withdrew from the study when they were assigned to the Sleep Fragmentation condition and several parents who completed the condition remarked that they had hoped not to be assigned to this group. Thus, parents were able to implement the night waking component of the procedure, but this did not always translate into a comparable reduction in sleep minutes.

### 3.5.3 Implications for Future Sleep Research

These findings are important to future sleep research with community preschool children. On the one hand, the control of variability in sleep times is optimal for any experimental

sleep protocol – the study design requires systematic differences in sleep between groups to compare outcomes and infer that sleep change causes changes in child functioning. On the other hand, many young children without reported sleep problems or behavioral difficulties do not readily sleep on a highly consistent schedule that would be needed for experimental sleep protocols. A possible way to improve protocol adherence might be to have research staff more involved in helping parents monitor adherence to detect variability in sleep more quickly. Actigraphy technology now allows remote uploading of sleep data. Rapid scoring and feedback to parents would allow for optimization of children's sleep schedules based on downloading and scoring actigraph data during the study, rather than relying on parent report to manipulate sleep schedules.

Although closer monitoring of sleep during baseline and experiment would allow for a study with greater group differences and improved statistical power, this procedure potentially reduces the ecological validity of results. Our study highlights that the regular schedules optimal for experimental sleep research do not reflect typical sleep schedules in the preschool period whether measured with parent diary or actigraph. This calls into question whether results from experimental studies with young children will inform our understanding of the effects of sleep restriction in the preschool period if only a limited subset of children can complete an experimental research protocol (Sitnick et al., 2008). To the best of our knowledge, no previous experimental studies of older children have examined intraindividual sleep variability, although variability in adherence to an experimentally-imposed sleep schedule has been discussed for older children (Fallone et al., 2002).

Participatory design research led to the creation of a protocol with smaller manipulations in participants' sleep compared to research with older children; variability in children's sleep based on diary and actigraph correspondence in this age group suggests that larger degrees of sleep restriction will be necessary to allow between-group comparisons. Alternatively, researchers could rely on within-subject protocols.

Individual child sensitivity versus resilience to sleep restriction, sleep variability, and sleep fragmentation requires additional research. Adult sleep research has found that some individuals are consistently more likely to experience negative outcomes from sleep deprivation, while others are relatively resistant to the effects of sleep loss (Ferrara & De Gennaro, 2001; Ramakrishnan et al., 2012; Van Dongen, Baynard, Maislin, & Dinges, 2004). Clinical recommendations for sleep in young children use ranges of recommended sleep times (e.g., between 10 and 13 hours per 24), reflecting common clinical and parental judgement that different children may require different amounts of sleep (Paruthi et al., 2016). However, individual differences in sleep needs remains almost entirely unexplored in pediatric sleep research, particularly in early childhood. Normative data reveal wide variability between children, ranging from about 14.8 to 9.5 hours per day amongst 3-5 year olds (Iglowstein et al., 2003). The lack of knowledge about the typical variability of sleep and individual differences in sleep requirements within early childhood has important implications for clinical recommendations regarding the evaluation of sleep needs and the degree of sleep disruption that should be diagnosed as a sleep problem. Future research should document the degree of sleep variation with objective sleep measures in children to obtain better normative data about sleep variability between and within children. Such research will help inform clinical

recommendations regarding the amount of sleep disruption or sleep variability that can be consistently related to clinical outcomes.

A foundational amount of sleep is certainly needed to support ongoing development, but it remains for sleep researchers to determine where the boundaries between clinically-significant and benign sleep loss lie during the early childhood period. This is a prime area for future investigators. The current study suggests that substantial daily variability in sleep duration is the norm in typically-developing preschoolers. Early child sleep variability appears to be at least as great as the degree that parents are generally willing to voluntarily restrict their children's sleep (i.e., between 20 and 40 minutes). This presents a challenge to future researchers who hope to implement experimental studies of child sleep restriction. Experimental studies of sleep restriction in young children, may reveal the role of sleep in child development, but may also lack ecological validity if they represent a small number of families willing to restrict children's sleep more than most.

## Chapter 4

### 4 **The effects of sleep restriction on executive functioning performance in 3- to 5-year-old children: A pilot study with a community sample**

Difficulties falling asleep or waking during the night may affect at least one-third of preschool-aged children in the general population (Ancoli-Israel & Roth, 1999; Mindell et al., 2009; National Sleep Foundation, 2004; Richman, 1981). Sleep problems are often identified clinically when parents have concerns for their child related to the child's sleep patterns or experience increased fatigue themselves (Boergers, Hart, Owens, Streisand, & Spirito, 2007; Eckerberg, 2004; Mindell et al., 2009; Thome & Skuladottir, 2005). Although the optimal amount of sleep at different points in childhood has been debated, there is still relatively little empirical research to demonstrate how much sleep preschool children need for healthy function and development (Anders & Dahl, 2007; Matricciani et al., 2013). Sleep is assumed to support brain development in early childhood, though causal demonstrations of this link are unavailable (Ednick et al., 2009), and sleep deprivation experiments in adults have demonstrated compromised functioning in areas including memory, vigilant attention, and emotional regulation. More empirical research is needed to support the assumption that sleep plays a causal role in supporting childhood cognitive and behavioural development. The purpose of the current study was to examine whether reduced sleep leads to decrements in specific domains of cognitive performance outcomes that are relevant to early childhood functioning, specifically between the ages of 3 and 5 years.

#### 4.1 **Sleep Problems in Young Children**

Early childhood sleep disruption that potentially leads to sleep deprivation is considered a *behavioural sleep problem*. Such sleep problems are often defined and



studied apart from sleep disruptions that are conceptualized as being primarily physiological (i.e., sleep disruption related to childhood sleep apnea, bed wetting). Given that behavioural sleep problems are common in early childhood, the outcomes of sleep deprivation at early ages are a key area of research that helps inform the need for sleep interventions. If many typically-developing children experience sleep problems, then deleterious outcomes that potentially result from such problems are important to quantify. Previous research in early childhood sleep problems has focused on the association between sleep and poor child adjustment outcomes, including parent-report of child behaviour using standardized instruments such as the Child Behavioural Checklist (Bruni et al., 2000; Goodnight, Bates, Staples, Petit, & Dodge, 2007; Hiscock et al., 2007; P. Lam, Hiscock, & Wake, 2003; Lavigne et al., 1999; Paavonen et al., 2009; Reid et al., 2009; Shang, Gau, & Soong, 2006; Touchette et al., 2007). Most of these studies have obtained information about child sleep problems from parents in the form of questionnaires that ask about problematic sleep. Paper-and-pencil measures are also common in clinical studies in which physicians, or other health professionals, ask parents a few questions about their child's sleep to determine the presence of sleep problems. Despite obvious strengths, paper-and-pencil measures do not specify how much or how often a child experiences sleep problems. Consequently, we know broadly that parent-reported sleep problems are linked to poorer psychological adjustment in children, but it is unclear whether the degree or frequency of sleep disruption can be causally implicated in childhood behavioural problems.

The number of night awakenings and the degree of bedtime delay that occur as part of a behavioural sleep problem correspond to the child's potential restricted sleep

time. Anders and Dahl (2007) published guidelines to inform when sleep disruptions might represent a significant pattern of problematic sleep for infants, toddlers, and preschoolers. Their proposed criteria were a minimum of 20 minutes sleep disturbance in either delayed sleep (sleep restriction) or cumulative minutes awake at night (sleep fragmentation) as a threshold for clinically significant sleep problems; frequency of the problem, (at least 2 awakenings per night) was used to denote the severity of a night waking problem in children over 3 years of age (i.e., perturbation: one episode per week for a month; disturbance: 2-4 episodes per week for a month; disorder: 5-7 episodes per week for at least a month). Similarly, sleep onset problems were classified in these guidelines as episodes in which child meets 2 of 3 criteria: more than 20 minutes to fall asleep, requires a parent in the room to fall asleep, or returns to the parent more than twice after being settled to bed. According the guidelines, sleep onset problems, like night waking problems, could be classified as a perturbation (one episode per week for a month), a disturbance (2-4 episodes per week for a month) or a disorder (5-7 episodes per week for a month) (Anders & Dahl, 2007). The guidelines were published explicitly to provide a common working definition of problematic sleep patterns that would benefit from further study in order to pinpoint their presumed deleterious effects. However, the guidelines represent divisions chosen by expert discussion and agreement without the benefit of empirical data (Anders & Dahl, 2007). Therefore, a research protocol that specifically examines the impact of 20 minutes of sleep disruption on child functioning outcomes would provide essential empirical data to advance our understanding of childhood sleep disruptions, particularly in light of the choice of greater than 20 minutes to fall asleep being considered a departure from sleep onset norms in the guidelines.

#### 4.2 A Potential Link Between Child Sleep and Executive Functioning

Sleep's apparent role in supporting child functioning suggests that sleep outcome assessments should include measures that tap into domains of behavioural control and regulation. A domain that may be particularly vulnerable to disruption from sleep restriction is executive function. Executive function (EF) represents a set of skills thought to reflect behavioural and emotional control, as well as skills related to planning and problem solving (Bridgett, Oddi, Laake, Murdock, & Bachman, 2013; Diamond, 2002; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). EF includes inhibition of dominant responses in relevant contexts, as well as holding information in working memory to solve problems. EF skills undergo a protracted period of development and some cognitive functions within the EF domain appear to emerge during the preschool period (Garon et al., 2008). EF skills may be particularly vulnerable to sleep disruption in early childhood for two reasons. First, skills that are in the process of developing or have only recently developed may be more vulnerable to deterioration under stressful conditions. In this context, sleep disruption could be a particular stressor that leads children to perform more poorly on EF-based tasks that they have only recently mastered. Second, the findings from previous research suggest that a disruption of emotional self-regulation, through sleep deprivation, could account for some of the behavioural and psychological adjustment problems reported in children with sleep problems (Dahl, 1996a; Friedman, Corley, Hewitt, & Wright, 2009; Hatzinger et al., 2010; Turnbull et al., 2013).

Executive function in preschoolers can be assessed in a number of ways. Laboratory and observational self-regulation assessments for preschool children have

been designed to include appealing rewards that will enhance children's motivation and emotional investment, such as gambling-type tasks (Garon & Longard, 2015). Delay of Gratification is now a classic research paradigm of self-regulation (Mischel & Ebbesen, 1970) that measures a child's ability to wait for a larger reward in a challenging context. In the classic version of this task, children wait at a table in an empty room with a snack that they enjoy, such as cookies or pretzels, on the table. Children are promised that they can have an even larger snack if they refrain from eating the food items until the experimenter returns (Mischel & Ebbesen, 1970). Longer delays are related to concurrent measures of executive functioning (Lemmon & Moore, 2007) (Hongwanishkul, Happaney, Lee, & Zelazo, 2005) and longitudinal measures of social adjustment, coping, and academic achievement (see work of Mischel). If sleep disruption in early childhood has an impact on self-regulation, then children should have more difficulty waiting for an appealing reward in a delay of gratification task when they have experienced recent sleep disruption compared to children who have not experienced sleep disruption.

#### **4.3 The Experimental Study**

The current study evaluated the impact of three nights of sleep disruption on executive functioning in children between the ages of 3- and 5-years. Children were randomly assigned to one of four groups that differed in terms of the amount of sleep disruption. Two groups experienced three consecutive nights of sleep restriction, including groups with 20-minute and 40-minute bedtime delays respectively. A third group experienced three consecutive nights of sleep fragmentation, operationalized as being woken 20 minutes after going to sleep. A fourth control group had no change from their normal bedtime routine on three consecutive evenings. Children assigned sleep

disruption conditions were expected to perform more poorly on outcome measures of response inhibition, verbal working memory span, visual-spatial working memory, and delay of gratification compared to children in the control condition. Some of the children were assessed more than once on the outcome measures. We expected children in the control group not to differ on the outcome measures when tested twice, while children who were retested were expected to perform better on outcome measures compared to their performance after their assigned sleep disruption condition.

#### **4.4 Method**

##### **4.4.1 Participants**

Parents were recruited to participate in the study with their 3- to 5-year-old children using online advertisements and community flyer distribution (see Chapter 3). A parent telephone interview screened participants for eligibility. Participants were excluded if their parents reported that the prospective child participant had current sleep problems, regularly slept with another family member, or had a previously-diagnosed behavioural/ emotional/ medical condition (e.g., Attention Deficit/Hyperactivity, nocturnal asthma) that might interfere with sleep. The Research Ethics Board at the authors' academic institution approved all procedures for recruitment, screening, and data collection. The majority of parents who completed the study were married and most had completed post-secondary education. More detailed demographic characteristics of the participating families are presented in Table 4.1.

**Table 4.1***Demographic Characteristics of Participating Families (N = 53)*

	n (%) <sup>*</sup>
Parent Marital Status	
Single	4 (7)
Common-Law	2 (4)
Married	47 (89)
Highest Education (Primary parent participant)	
Some secondary school	2 (4)
Complete secondary school	3 (6)
Some postsecondary school	11 (21)
Complete Diploma/College/Trade	11 (21)
Complete Bachelor's Degree	19 (36)
Complete Master's/ Doctoral Degree	5 (9)
Complete Professional Degree (e.g. Law)	2 (4)
Children at home	
One	10 (19)
Two	22 (42)
Three	14 (26)
Four or more	7 (13)
Annual Household Income	
under \$20 000	5 (10)
\$20 000 - \$39 999	6 (11)
\$40 000 - \$59 999	7 (13)
\$60 000 - \$79 999	9 (17)
\$80 000 - \$99 999	12 (23)
\$100 000 and over	13 (24)
Declined to respond	1 (2)
Language Spoken at home	
English	51 (96)
Other (Arabic, Mandarin Chinese)	2 (4)

\* Percentages may not add to 100 due to rounding

Of the 75 children enrolled in the study, three were withdrawn during the baseline sleep measurement phase ( $n = 2$  for refusal to wear actigraph;  $n = 1$  when the child started to sleep on an irregular schedule at the start of the study and the parent withdrew the child), two withdrew before the outcome assessment ( $n = 2$  parents withdrew the child when assigned to Group 4, described below), and one was withdrawn from the analysis ( $n = 1$  at end of study the parent reported that their child had a previous head injury with loss of consciousness). A further 15 children who completed the study did not have actigraph data due to technical failures. Actigraph data were therefore available for 54 participants (Mean age = 4.3 years,  $SD = .88$ ; 27 boys). We further excluded individual days of actigraph data on which parents reported that their child had either fallen asleep in a car or stroller, or had been ill/ required medication for allergies during the study. Eighteen children had at least one night of their actigraph data excluded for one of these reasons. Overall, 53 children had sufficient actigraph data for analyses.

#### 4.4.2 Measures

**Sleep: Actigraphy.** Actigraphs are worn on the body and measure sleep through recording motion to provide an objective measure of sleep and wake states. Child sleep was measured using the Ambulatory Monitoring MicroMini Motionlogger actigraph units (Ambulatory Monitoring Inc., 2010). The Zero-Crossing Mode (ZCM), which measures activity in 1 minute epochs through a 24-hour period, was used for data collection. Actigraph units were initialized for data collection using the *ActMillenium* 4.0 software program (Ambulatory Monitoring, 2010), and data was downloaded from devices using the same program. Actigraph sleep was scored only within 30 minutes of diary-reported children's time to fall asleep and child time to wake up, according to standard actigraph

scoring protocols (Acebo et al., 2005; Sadeh et al., 1991). Raw activity data was automatically scored based on 1-minute epochs using the Sadeh sleep scoring algorithm (Sadeh et al., 1991) in the *Action4* 1.1 software program (Ambulatory Monitoring, 2010).

Actigraphs have been used extensively in child sleep research to provide objective measures of nocturnal sleep onset, duration and timing of nocturnal awakenings, and morning awakening; from these variables sleep duration and sleep efficiency can be calculated (Acebo & Sadeh, 1999; Acebo et al., 2005; Epstein et al., 1997; Fallone et al., 2002; Tikotzky & Sadeh, 2001). Actigraph measurement of sleep in children age 1 to 4 years has been validated against polysomnography, the gold standard for sleep measurement (Sadeh et al., 1991). For the current study, sleep restriction was calculated by subtracting the total average actigraph-recorded sleep time during the three experimental days from the total average actigraph-recorded sleep time during the baseline sleep measurement.

**Sleep: Parent Diary.** Parents used a structured diary to record their children's sleep each day. In the diary, parents completed fields noting the time their child went to bed (i.e., when the lights were turned off so the child could initiate sleep), the time their child actually went to sleep, the duration of any waking during the night, and the time the child woke for the day the following morning. Parents also reported the beginning and end of their child's daytime nap each day, if applicable. Additional space was left blank on each diary day for parents to record any unusual positive (e.g., special family visitor) or negative (e.g., illness) events for their child or family on each day during the study. Caregiver sleep diaries are required to ensure that actigraph motion and sleep data is coded correctly (Acebo et al., 2005; Sadeh, 2008), as data may erroneously be recorded



as sleep when an actigraph is removed if a diary report of sleep start and end times is not provided. Sleep diaries have also been used in several pediatric sleep studies and have been shown to provide good agreement with actigraph-confirmed sleep variables (95% of scores are within 30 minutes of an objective measure of sleep onset and sleep end time) (Werner et al., 2008). The diary for the current study was adapted from one developed by Corkum and colleagues for home-based sleep research with school-aged children (Corkum et al., 2001; Vriend et al.). The sleep diaries were used to confirm actigraph-recorded sleep periods.

**Sleep: Children's Sleep Habits Questionnaire.** The Children's Sleep Habits Questionnaire (CSHQ) (Owens, Spirito, & McGuinn, 2000) is a parent report measure of common childhood sleep problems and daytime sleepiness in the past week. Items 1-35 refer to specific sleep behaviours and are rated on a 3-point Likert scale (1 = *[Rarely] 0-1 nights/week*; 2 = *[Sometimes] 2-4 nights/week*; 3 = *[Usually] 5-7 nights per week*). Seven additional items refer to daytime activities in which children may display sleepiness and are rated on a 3-point Likert scale (1 = *Not Sleepy*; 2 = *Very Sleepy*; 3 = *Falls Asleep*). Higher scores on the CSHQ reflect greater levels of sleep problems in eight areas: 1) Bedtime Resistance, 2) Sleep Onset Delay, 3) Sleep Duration, 4) Sleep Anxiety, 5) Night Wakings, 6) Parasomnias, 7) Sleep Disordered Breathing, and 8) Daytime Sleepiness. A total score of overall sleep problems can be calculated from the CSHQ, as well as subscale scores reflecting the eight specific areas of potential sleep problems in children.

The psychometric properties of the CSHQ were first assessed with a sample of children age 4-10 from both the general population and a sleep disorders clinic (Owens et

al., 2000). The authors reported adequate internal consistency of the total CSHQ scores in the community,  $\alpha = 0.68$ , and clinical samples,  $\alpha = 0.78$ , and also reported adequate test-retest reliability for the eight subscales ranging between  $r = 0.62$  and  $r = 0.79$ . Children referred for assessment and treatment of sleep problems scored significantly higher on the CSHQ than children in the general population, supporting the validity of the instrument as a screening tool (Owens et al., 2000). A second study of the CSHQ (Goodlin-Jones, Sitnick, Tang, Liu, & Anders, 2008) confirmed that 2- to 5-year-old children with parent-reported sleep problems obtained significantly higher CSHQ scores than children without parent-reported sleep problems. A comparison of the preschool and toddler sample scores on the CSHQ for non-problem sleepers with those of the community sample reported in the original CSHQ research revealed that all subscales of the CSHQ were significantly greater for the younger sample of children, except for the Sleep Disordered Breathing Scale (Goodlin-Jones, Sitnick, et al., 2008). Subscale comparison of mean scores for each subscale in the current sample were similar to those reported for preschool-aged non-problem sleepers (Goodlin-Jones, Sitnick, et al., 2008).

Five outcome measures of executive function and attention performance were administered for the study. The tasks administered on the computer (Reaction Time, Response Inhibition, and Visual-Spatial Working Memory) were programmed using EPrime (Tools, 2005).

**Reaction Time.** A visual-motor reaction time task was created to measure basic attention and processing/response speed in participants. Child participants were seated in front of a laptop computer and instructed to push the spacebar of the computer keyboard when they saw the visual target appear on the screen. To make the task child-friendly, the

visual target was a cartoon picture of a rabbit, and children were instructed to “push the button as fast as you can to make the bunny disappear.” Children were also instructed to place their hands on a red piece of cardboard fixed to the front of the computer keyboard between trials. A practice phase of 10 trials (10 stimulus appearances) was administered before the test phase during which the experimenter controlled the appearance of the target and gave the child prompts to keep paying attention to the laptop screen, to respond as quickly as possible and to return both hands to the red card after each response. The test phase consisted of 20 trials with each trial terminating when the child pushed the spacebar in response to the target. The delay between each target presentation was randomly varied by one second between two and six seconds to ensure that the child was responding to the appearance of the target, rather than responding in a rhythmic automatic fashion. During the test phase, the experimenter provided no corrective feedback, other than to prompt the child to keep going with the task until it was complete.

The task performance score was calculated as the child’s average reaction time in response to the target. Reaction times to individual trials that were less than 500 milliseconds were coded as false positives (i.e., button presses that were likely engaged before the child could have viewed the target), and reaction times that were greater than 5500 milliseconds were coded as misses, indicating a failure to attend to the trial. These times are slower than those used for reaction time tasks in older children and were chosen based on previous research that measured reaction time with participants in the age range of our sample (Weissberg, Ruff, & Lawson, 1990).

Response time to a stimulus is not a measure of executive functioning, but reliable response times indicate the capacity for sustained attention and therefore the underlying

ability to engage in higher level cognitive processes. Basic reaction time paradigms, such as the psychomotor vigilance task, have been used to measure sleep deprivation effects in adults (Lim & Dinges, 2008). Psychomotor vigilance has also been validated in school-aged children (Peters et al., 2009; Wilson, Dollman, Lushington, & Olds, 2010), but not with children younger than age 10 years; therefore we used the best available research for typical reaction times in this age group to design and score this task. Greater variability in reaction time would reflect less ability to maintain appropriate vigilance to the task. As such, the standard deviation of reaction times for each child was calculated as an outcome measure.

**Response Inhibition.** Response inhibition was measured using a Go/No-Go task using parameters previously studied in 3-year-old children (Simpson & Riggs, 2006). The task consisted of 24 “Go” targets in which children had to press the keyboard space-bar in response and 6 “No-Go” targets in which children had to refrain from pressing the space-bar. Each target was presented for a maximum time of 2 seconds with an interstimulus interval of 1.5 seconds. Children were introduced to the Go/No-Go task as the “Cat and Mouse Game” and were told to push the button when they saw a picture of the mouse (the Go target) and not to push the button when they saw the picture of the cat (the No-Go target). Children responded to 10 presentations of stimuli alternating between Go and No-Go targets for practice before the test phase to ensure that they understood the rules and could respond appropriately: for a few children who missed hitting more than one Go target during the practice phase, the 10 practice trials were repeated.

A greater proportion of Go trials to No-Go trials establishes the button press as the dominant response. Behaviour inhibition is measured by the number of No-Go trials

the child responds to correctly (i.e., failing to press the button when the No-Go target appears). Therefore, a greater number of errors indicates reduced behavioural inhibition. Simpson and Riggs (2006) established that the timing used for this task allows preschoolers sufficient time to respond to the “Go” stimulus, but also proceeds quickly enough to make it challenging to refrain from an incorrect button press to a No-Go stimulus. Performance scores were based on the number of errors (incorrect button presses when the cat stimulus appeared) as well as the number of overall correct responses.

**Verbal Working Memory.** Verbal working memory was assessed using a digit span task for preschoolers (Gathercole, 1995). Digit span tasks require individuals to repeat sequences of non-sequential numbers presented orally (e.g., 2–6–3), and are widely used in the assessment of working memory in both children and adults (Girofrè, Mammarella, & Cornoldi, 2013; Michalczyk, Krajewski, Preßler, & Hasselhorn, 2013; Ostrosky-Solis & Lozano, 2006). The digit span task for the current study was presented as a “number game” where the experimenter presented the numbers to the child participants using a monkey puppet. The experimenter told the children that the monkey would say the numbers and the children would have to say them back the same way (i.e., forward digit span). For practice, the children were presented with two numbers to see if they would repeat them correctly. Once the children repeated the two practice numbers correctly, the experimenter presented the test sequences of the digit span task. Children were presented with two sequences of numbers at each sequence length, with numbers presented at a rate of approximately one per half second (i.e., two sequences of two digits, two sequences of three digits, etc.). Each correctly repeated sequence was given a

score of 1, and incorrectly repeated sequences were given a score of 0. When children repeated two sequences of the same length incorrectly, the task was ended. Children who repeated one sequence correctly and one sequence incorrectly of the same length were given a third sequence; if the child repeated the sequence correctly, he/she continued to the next level, but if he/she repeated it incorrectly, the task was ended. The child's score for this test was the total number of sequences that the child repeated correctly.

**Visual-Spatial Working Memory.** An assessment of visual-spatial working memory was developed for the current study, based on the Noisy Book Task (Hughes, 1998; Hughes, Dunn, & White, 1998) to assess working memory in preschoolers. The child was presented with a display of nine 3 cm x 2 cm boxes spaced 1.5 cm apart on all sides in a 3 x 3 matrix on the screen. For introduction to the task, the child was instructed to touch each box on the touch screen to “see the animal hiding in the box.” Response data for the task were programmed to be received through the touch-screen function of the laptop computer. One of nine different cartoon animals would appear in each box when the child touched it. This phase served to familiarize the child with touching the screen to give a response, as well as with the positions of the different animals, which did not change during the task.

In the first test phase of the task, the child was required to remember where one animal had appeared after a delay. In subsequent phases of the task, the child was required to remember where more than one animal had appeared, and point out the boxes in the same sequence as they remembered seeing the animals appear. The animal(s) were each visible for two seconds and appeared one after another. After each animal in the sequence had been presented, a cartoon picture of a clock appeared for a delay period of

five seconds before the 3 x 3 array of boxes appeared again and the child could respond. If the child did not point right away to a box on the computer screen after the delay, the experimenter would remind the child to touch the box(es) where they remembered seeing the animal(s) hiding. The child was awarded 1 point for each correctly-reproduced sequence. Each child completed three trials at each level of difficulty (i.e., three trials where one animal was presented, three trials where two animals were presented, three where three were presented, etc.) and continued to advance to the next level of difficulty until the child failed all three trials at a given level. To ensure that children understood that they had to reproduce the sequence of animals that appeared before the delay as well as the correct locations, there were four trials presented where two animals appeared in sequence and the first of the four was treated as a practice trial. Children were given corrective feedback after the first of these four trials if they responded with the correct locations of the two animals, but not the correct sequence. Otherwise, no corrective feedback was given during the task. The animals did not reappear to confirm or disconfirm the child's choice of location or sequence during the testing phase.

Throughout the task, the experimenter scored the child's responses on a scoring sheet in order to determine when the task was finished (i.e., when the child did not respond correctly on any of the trials at a given level of difficulty). The child received two points for each sequence they identified correctly in order during the task. Children were also awarded one point if they identified all the animals in the correct locations, but not in the correct order. Each child's overall score was the sum of these points over the trials of the Visual Spatial Working Memory task.

**Delay of Gratification.** A delay of gratification task tests a child's ability to defer an immediate small reward in favour of a delayed, but larger reward (Mischel & Ebbesen, 1970). In this task, each child was presented with a selection of five small toys in a clear plastic bag. The child was asked to point to the two toys in the bag that they would like to play with most. Once the child had selected two toys, the experimenter took these out of the bag and asked the child if he or she would like one or both toys to keep. The experimenter then told the child that she had to leave to talk to the child's parent and would leave one of the toys while she was gone. The child was told he or she could play with the toy that was left behind, but if he or she did not touch or play with the toy, the experimenter would allow the child to keep both toys at the end of the session. The toy left with the child was placed on a 12.5 cm<sup>2</sup> plastic target in the middle of a flat board in front of the child. The experimenter left the room to speak to the child's parent and began timing the delay period on a stop-watch so that the child was left alone to wait for a maximum of 10 minutes.

The delay of gratification task was scored according to the amount of time the child waited before picking up the toy or moving the toy off of the 12.5 cm<sup>2</sup> plastic target. Longer waiting time corresponds to better performance in delay of gratification. Some children spontaneously left their seat during the task to come and find their parent and the experimenter. If the child did this, the child was told that "Waiting means you have to stay with the toy. Are you finished waiting?" If the child said he or she was finished, this was considered to be the end of their waiting time and the child was scored based on when he/she left the room. Otherwise, the child returned to the task and continued to wait until the time was up, or the task was otherwise terminated by the child



playing with the toy. The time the child waited in the task, the time the child spent looking away from the toy, and the number of times the child touched the toy were scored from a video of the task, as described below in the Video Coding subsection.

#### 4.4.3 Procedure

A research team member visited parents on the first day they were to participate in the study. At the first home visit, the researcher reviewed how to complete the sleep diary each day and the parents provided informed consent on behalf of himself/herself and his/her participating child. Parents were asked to complete the child questionnaires during the first few days of the study and to complete the sleep diary each day indicating when the child was asleep and awake, as well as when the actigraph was removed during the week. The researcher also confirmed the child's usual bedtime and waking time and asked the parent to keep this as consistent as possible during the first seven days of the study (the baseline phase).

Participants were randomly assigned to one of four experimental sleep groups, using blocked randomization by child age in years to maintain equivalent age distribution in each experimental group. A research assistant not involved with the testing telephoned the parent before the last day of baseline and gave instructions about how to adjust the child's sleep for their assigned condition based on the parent report of the child's sleeping and waking during baseline. The required sleep changes in each group took place in the last three nights of the study (Days 8, 9, and 10). Children in Group 1 (Control) were to maintain their regular sleep schedule. Children in Group 2 (Sleep Restriction) were to go to bed 20 minutes later than their usual bedtime and wake at their usual time each morning. Children in Group 3 (Sleep Restriction) were to go to bed 40 minutes later than

their usual bedtime and wake at the usual time each morning, resulting in sleep restriction. Finally, children in Group 4 (Sleep Fragmentation) were to maintain their usual bedtime and wake time, but were required to wake for 20 minutes during the night, resulting in sleep fragmentation. Parents were asked to wake their children approximately one hour and 15 minutes after their child had fallen asleep, based on normative data suggesting that children would be less likely to be in a deep sleep stage at this point and easier to wake (Scholle et al., 2011). After the night of Day 10, the research assistant collected the actigraph, questionnaires, and sleep diary from the family at a final home visit and obtained feedback from the participating parents on their experience of the study. At this visit, the child completed the outcome assessment.

Thirty participating families were contacted 3-4 weeks after completing the study and invited to participate in the sleep measurement component of the study a second time. The purpose of this second assessment was to compare children's performance on outcome measures across time without the experimentally-imposed sleep condition. Parents and children completed the same sleep measurement procedures (actigraphy and sleep diary) for seven consecutive days, but the questionnaires were not re-administered. All parents were instructed not to make any changes to their child's sleep during this second participation period.

#### 4.4.4 **Video Coding**

Video recording was approved after recruitment and was implemented for case #005, the fifth child enrolled in the study. Video was available for 48 participants; additional video data was missing due to recording difficulties or because the video equipment was not taken to the home visit. A research assistant who was blind to

participant group assignment and to children's recorded sleep was trained to code the relevant child behaviours from the video of the Delay of Gratification task. A second trained research assistant blinded to the same variables as the main coder, coded a random selection representing 25% of the videos. A two-way random effects model based on average measures was used to calculate the intraclass correlation determining consistency between raters. Coders were in 100% agreement for the number of seconds children had waited for Delay of Gratification (1.0; 95% C.I. = 1.0 – 1.0). Coders were also highly consistent in rating touching the toy (.89; 95% C.I. = .77 – .95), and looking away from the toy (.85; 95% C.I. = .69 – .93).

## 4.5 Results

### 4.5.1 Preliminary Analyses

The average child age in each group was compared and confirmed that age did not differ across the experimental groups after the exclusion of participants with no available actigraph sleep data  $F(3, 50) = .160, p = .92$ . There were also no significant differences between groups for sleep problems on the CSHQ  $F(3, 50) = 2.39, p = 0.08$  (see Table 4.2).

**Table 4.2**

*Average Age, Behaviour, Emotion Characteristics and Achieved Sleep Restriction by Assigned Experimental Group, and Summary of Outcome Variables*

Measure	Control <i>n</i> =15	Group 2 <i>n</i> =12	Group 3 <i>n</i> =15	Group 4 <i>n</i> =12
	M (SD)	M (SD)	M (SD)	M (SD)

Age (years)	4.2 (0.86)	4.4 (0.87)	4.4 (0.86)	4.3 (1.02)
Sleep Problems – CSHQ	50.8 (3.80)	50.0 (5.24)	54.6 (5.79)	51.2 (4.73)
Average Minutes of Sleep Restriction	10.2 (33.1)	11.2 (50.1)	24.3 (27.0)	-27 (121.3) <sup>+</sup>
Outcomes				
Reaction Time Task (ms)	1335 (536)	1257 (528)	1511 (632)	1369 (659)
Reaction Time variability (ms)	938 (1432)	1177 (1394)	1099 (981)	1243 (1807)
Go/NoGo: Hit NoGo target	1.4 (1.4)	1.0 (1.0)	1.0 (1.1)	0.92 (0.9)
Go/NoGo: Correct Responses – both Go and NoGo	24.3 (5.6)	25.5 (4.8)	25.2 (4.7)	25.3 (6.5)
Verbal Working Memory Score	5.1 (1.4)	5.4 (1.7)	5.3 (1.5)	5.4 (2.0)
Spatial Working Memory Score	3.9 (3.0)	3.6 (2.7)	3.8 (2.8)	4.4 (2.8)
Delay of Gratification – Wait Time (% short wait; less than ½ session)	60%	50%	27%	58%

CSHQ = Children’s Sleep Habits Questionnaire

ms = milliseconds

+ The mean and standard deviation in Group 4 are overly influenced by a single participant whose sleep was significantly longer in the experimental phase compared to the baseline: with this outlier removed, the average sleep restriction minutes in Group 4 was 5.5 ( $SD = 46.8$ )

The study was designed to allow for a comparison of executive functioning performance skills based on children’s randomly-assigned sleep restriction. The distribution of sleep differences within each group revealed that there were participants in all groups who achieved more sleep on average during the last three experimental days compared with the baseline phase, and there were participants in the control group who achieved less sleep than baseline (see Chapter 3). Overall, only 45% of cases (*i.e.*,  $n = 24$ )

were deemed to have complied with the experimental protocol citation (see Chapter 3). Sleep restriction among participants was not normally distributed during the experimental phase (skewness  $z = 1.69$ ; kurtosis  $z = 1.70$ ). Therefore, the relationship between sleep restriction and outcomes was examined using Spearman correlations, as a non-parametric analysis for executive functioning performance outcomes scored with continuous variables.

#### 4.5.2 Executive Functioning Performance: Between-Subjects Comparison

The two reaction time outcome variables were not significantly related to sleep restriction, and 3 of the 4 EF outcome variables were not significantly related to children's sleep restriction in the study (see Table 4.3). The three behavioural variables in the Delay of Gratification task were all related to children's sleep. Contrary to the hypotheses, children who were more sleep restricted at assessment compared to their baseline sleep waited significantly longer in the delay of gratification task  $r_s(47) = .39, p = .007$ , and also spent more time looking away from the toy during the task  $r_s(47) = .33, p = .024$ . Conversely, children who achieved less sleep restriction spent more time touching the toy,  $r_s(47) = -.29, p = .049$ , while waiting during the task.

**Table 4.3**

*Distribution of Outcome Variables and their Relationship to Amount of Sleep Restriction Obtained in the Experimental Phase of the Study*

Outcome	N	Time 1 Day 10 of the experimental procedure		N	Time 2 1 month after Time 1	
		$r^+$	$p$		$r^+$	$p$
<hr/>						

Average Reaction Time	53	.17	.22	15	-.54	.04*
Reaction Time Variability	53	-.13	.18	15	-.49	.06
Go/NoGo: NoGo Errors	53	-.06	.69	15	.03	.92
Go/NoGo: Correct Responses	53	.01	.96	15	.07	.80
Digit Span Score	53	.09	.53	15	-.22	.43
Spatial Working Memory Score	53	-.24	.09	15	-.11	.70
Delay of Gratification – Wait Time	47	.39	.007*	14	-.01	.97
Delay of Gratification – Touching Toy	47	-.29	.049*	14	.12	.68
Delay of Gratification– Looking Away	47	.33	.024*	14	.38	.18

\*All reported *rs* are Spearman tests because measured sleep restriction was not normally distributed.

+Sleep Restriction (difference in average baseline sleep time and average experimental sleep time) was associated with outcome variables in Time 1 and Sleep Difference (difference between average experimental sleep time and average follow up sleep time) was associated with outcome variables in Time 2

The association between Spatial Working Memory performance and sleep restriction,  $rs(53) = -.24$ ,  $p = .09$  did not achieve statistical significance in this sample. Power analysis using the G\*Power software program (Faul, 1992-2019; Faul, Erdfelder, Buchner, & Lang, 2009) suggested that a total sample size of  $N = 183$  would have found a significant relationship (for power equal to 0.95). Necessary sample sizes for average reaction time  $rs(53) = .17$ ,  $p = .22$  and reaction time variability associations  $rs(53) = -.13$ ,  $p = .18$  were  $N = 370$ , and  $N = 636$ , respectively. Other observed associations (see Table 4.3) had very small associations, and so prospective sample sizes were not estimated.

#### 4.5.3 Executive Functioning Performance: Repeated Measures Comparison

Of the 21 participants who completed a second 7-day sleep measurement and executive functioning assessment about a month after their original participation session, 6 were missing actigraph data due to technical recording failures, resulting in an overall sample size of  $n = 15$  with sleep data at both the first and second measurements. Overall, there were no differences in the amount of time children slept within a 24 hour period between the 7 days of baseline sleep measurement before the experiment and the 7 days of follow-up  $t(2, 14) = -.68, p = .51$ . The relationship between delay of gratification and sleep restriction at the second assessment was examined using visual comparison scatterplots to explore further explore the lack of association between sleep and delay of gratification at the second assessment, given their association at first assessment. Scatterplots of sleep restriction and delay of gratification performance are presented in Supplementary Figure 4A.

An examination of performance on the outcome measures (including all participants with available assessment data at 2 time points,  $n = 20$ ) showed that there was a significant correlation between the first and second administration of the reaction time task  $r(18) = .52, p = .02$ , the digit span task  $r(18) = .71, p < .01$  and the spatial working memory task  $r(18) = .73, p < .01$ . Supplementary Table 4A presents these data.

There were no significant relationships between any of measured EF outcomes and the difference in amount of sleep children obtained before their first assessment (the experimental condition) and their second assessment (the follow-up condition), as reported in Table 4.3. Longer average reaction times at the second assessment were significantly related to shorter average sleep durations at second compared to the baseline

assessment,  $r(13) = -.54, p < .05$ . However, the standard deviation of reaction times was not related to children receiving different amounts of sleep before their first and second assessments.

## 4.6 Discussion

### 4.6.1 Findings in the Context of Sleep Variability and Observed Restriction

Preschool aged children showed variability in their measured sleep across nights. Many who were assigned to a sleep restriction or sleep fragmentation condition did not show any measured decrease in their overall sleep over 24 hours, while some children in the control condition showed a decrease in their sleep relative to their measured baseline sleep schedules (mimicking an imposed sleep restriction). The sleep variability and problems adhering to assigned sleep conditions meant that it was not possible to perform the planned comparison of executive function scores between children who had experienced randomly-assigned sleep disruption. However, children's measured sleep disruption relative to their average sleep schedule allowed for an evaluation of how sleep restriction relative to typical sleep was associated with outcomes in these 3- to 5-year-old children.

Children's degree of sleep restriction was significantly related to their performance in the delay of gratification task in the between-subjects experimental phase of the test, but in the opposite direction expected. Children who slept less than usual in the three days before the assessment performed better on the delay of gratification task. These children waited longer while a toy was in front of them in order to receive an additional toy at the end of their waiting period. Furthermore, children who slept less before the assessment spent more time looking away from the toy during the waiting



period. In contrast, children who had less sleep disruption relative to their usual sleep schedule before the experiment spent more time touching the toy while they waited in the delay of gratification task. Children had been instructed not to play with the toy while they waited in order to win the two toys they wanted. While touching the toy was not considered playing with the toy, it was a behavioural marker of the child's attention being drawn to the toy. In contrast to looking away, this engagement with the toy represented a less effective strategy, which usually results in young children waiting for less time during delay of gratification (Mischel & Ebbesen, 1970). Thus, findings were the opposite of what was hypothesized.

Research assistants who presented the delay of gratification task to children did not prompt children with strategies that would allow them to perform better on delay of gratification, so children who waited longer or looked away from the toy were assumed to be using these waiting strategies spontaneously. Looking away involves directing attention away from an appealing reward (gaining two toys at the end of the task instead of one) and is a particularly effective self-regulation strategy for young children in the delay of gratification task (Mischel & Ebbesen, 1970; Mischel, Shoda, & Rodriguez, 1989). In contrast, directing attention to the toy through looking at it would tend to undermine future success in acquiring the two toys.

Given that sleep needs appear to be greater in early childhood relative to later childhood (Iglowstein et al., 2003), and that this increased sleep is felt to support ongoing brain development (Turnbull et al., 2013), the superior performance in delay of gratification for children who had slept less than usual was surprising. Furthermore, this finding does not appear to be an artifact of children's age being related to their measured

degree of sleep restriction for the study; preliminary analysis confirmed that age was not related to measured sleep restriction in this sample.

Children who experienced more sleep restriction might have been less engaged with the delay of gratification task due to fatigue. The task occurred at the end of the assessment procedure for all children and was relatively boring, in order to make waiting more challenging. Fatigue may have inadvertently contributed to children using more “successful strategies” that tend to increase waiting in this paradigm (Eigsti et al., 2006). Directing attention away from the desired object in delay of gratification tends to result in longer waiting times, and children who had less sleep may have looked away more often in response to the effects of recent sleep restriction. In contrast, children who were relatively well-rested may have been more interested in the toys due to their increased alertness. The observation that children touched the toy they were waiting to play with more often when they had experienced less sleep restriction suggests that they were very focused on the toy, perhaps because they were more alert compared to the children who had experienced less sleep before the assessment. The association in the current sample between shorter waiting times and more touching of the toys suggests that engaging with the toy led the children to have more difficulty waiting longer, replicating previous findings with this task.

#### 4.6.2 **Caveats for the Association between Delay of Gratification and Sleep**

At the same time, the results from the children who participated in two assessments indicates that these results for delay of gratification in between-subjects' sleep comparison may not generalize to other samples. The 14 children who completed the delay of gratification task and who also had actigraph-measured sleep records for

comparison at two time points did not show a significant effect between sleep and delay of gratification performance. In addition, the association between delay of gratification performance and children's sleep restriction, was not in the expected direction. The hypothesized direction of the association was necessary for supporting evidence between sleep restriction and EF skills, based on the theory that sleep restriction would tend to reduce performance. Longer waiting times in the context of greater sleep restriction does not support an association, or causal connection between sleep disruption and executive function. Furthermore, the degree of sleep restriction that children experienced was not related to performance on the attention task, or to performance on the executive function assessments of response inhibition (Go/No-Go) and working memory (digit span and spatial working memory), and those children who completed a second assessment did not demonstrate any association between their sleep and EF performance either. Therefore, even if further research found a similar association between reduced sleep and the executive functioning skills that contribute to successful delay, it would not still not suggest a role for restricted sleep having an impact on executive functioning in this age group.

While this study found no evidence to confirm that sleep disruption in young children leads to a diminished ability to perform on measures of executive functioning, it did suggest that young children between age 3 and 5, particularly children who regularly receive adequate sleep are resilient to mild sleep restrictions. The use of actigraphy in this experiment confirms that relatively small amounts of sleep disruption do not impair child performance in executive function skills. This may mean that children must experience sleep disruption for longer than 20 minutes per night, or for longer than 3 days in order to

observe changes in executive function performance. Experimental sleep research in early childhood requires the cooperation of parents as well as children and we found that many parents were not willing to disrupt the sleep of their young sons and daughters for very long or very many days for the purposes of a study. Nevertheless, the current research may provide reassuring information to parents and professionals that mild sleep disruptions in children who otherwise sleep well would be unlikely to result in any substantive cognitive or behavioural disruptions.

Children who participated in this study were specifically recruited to exclude those who experienced regular disruptions in their sleep patterns, according to parent report. Therefore, these results do not rule out the possibility that ongoing sleep disruptions in early childhood that last for weeks, months or years would disrupt executive functions. Although it may not be feasible to recruit young children (and parents) who are experiencing ongoing sleep problems for a sleep restriction experiment, an intervention study might be an option for future research. A study where children with sleep problems were randomly assigned to behavioural sleep treatment or no treatment conditions, with executive functioning assessment performed before and after intervention might reveal a role for *improved* executive function after *improved* sleep. There do not appear to be many behavioural sleep intervention studies that measure early childhood functioning outcomes, other than improvements in sleep itself. Such studies might represent an alternative way to assess the potential contribution of sleep disruption to development. Furthermore, dramatic improvements in daytime emotional regulation have been reported anecdotally as the basis for theories that connect childhood sleep and daytime behavioural and emotional functioning, including serious problems that meet

criteria for early psychopathology (Dahl, 1996b). Additional measures of executive function that are sensitive to developmental differences in early childhood have recently been validated for use with younger children (Boudreau, Dempsey, Smith, & Garon, 2017; Garon, Smith, & Bryson, 2014), making this an optimal time to improve our understanding of these executive functions in early childhood. Future sleep intervention studies that include developmentally sensitive measures of executive function in children may begin to clarify how regular sleep specifically contributes to healthy development in early childhood.

## Chapter 5

### 5 General Discussion

The goal of this dissertation was to design and conduct the first experimental study in which preschool aged children (between 3 and 5 years old) experienced restricted or fragmented sleep overnight. The impact of sleep restriction/fragmentation was measured according to executive functioning performance, a theoretically important construct in early childhood development. The first study of this dissertation recruited parents to help create an experimental study in which the child was sleeping at home; the design was informed by previous research with sleep deprivation in school-age children (Sadeh et al., 2003; Vriend et al., 2013). The potential challenges of applying such a paradigm to preschool children were explored with parents. Through participatory design (Spinuzzi, 2005), a useful but underexplored methodology for designing pediatric behavioural research, thoughtful planning and feedback were sought to create a strong, viable experimental design. The approach was particularly useful to accommodate the needs of the parents and young children who participated in the experimental study.

In the second study (Chapter 4), children's typical baseline sleep was measured in their home environment before experimental manipulations began. Parent interviews from the earlier participatory design study (Chapter 2) allowed for an experimental study that respected the preferences of both the preschool children and their parents. This is the first experimental study with preschool-aged children to include an experimental sleep fragmentation condition to investigate the impact of sleep disruption at night. The results also provided novel insights into the sleep practices of young children, which have so far received relatively little empirical investigation.

This dissertation informs potential future research in pediatric sleep in two general domains. First, the data raise issues pertinent to designing and conducting sleep studies with 3- to 5-year-olds in light of normal variation in their sleep. Second, this dissertation has theoretical implications regarding our understanding of sleep during early childhood. Third, it has highlighted challenges related to measure EF in the context of sleep restriction studies with preschool-age children, Finally, this dissertation has brought to light deficiencies in sleep measurement with the preschool developmental period. These implications are explored in the next four subsections.

### **5.1 The Methodology of Experimental Sleep Restriction with Young Children**

The current dissertation brings to light four methodological issues about the use of sleep restriction protocols with young children. These are as follows: a) the consideration of normal sleep in relation to restricted sleep protocols; b) the use of actigraphy for experimental sleep restriction, c) the measurement of sleep outcomes based on restriction from baseline sleep, and d) accounting for individual differences in resilience to sleep restriction. These four issues are discussed in detail in the current section.

**(A) Duration of sleep restriction protocols in light of normal sleep.** These findings add to other recent work using an experimental paradigm to study the effects of sleep restriction in children 3 – 5 years of age (Berger et al., 2012; Miller et al., 2015; Schumacher et al., 2017). Past studies with preschool children have used restriction of naps, not night-time sleep. The current experimental study was conceived as a feasibility study to guide future work, given that the experimental sleep manipulations used were novel for this age group. The number of nights chosen for sleep restriction – 3 nights – had been guided by the participatory design study and feedback from parents (see

Chapter 2). Parent reports of what they were willing to do informed the duration of sleep disruptions used in the experimental study. In addition, the proposed thresholds for defining sleep perturbations and disturbances (i.e., sleep issues at a level of concern considered to be significant in early childhood) were taken into consideration when the duration for sleep restriction was chosen (Anders and Dahl, 2007). These authors proposed that taking more than 20 minutes to fall asleep in children over the age of 2 years could be considered a useful definition of “Sleep Disturbance,” when such episodes took place between two to four times per week. The choice to use 3 nights of either 20 minutes or 40 minutes sleep restriction (as well as 20 minutes in the sleep fragmentation condition) was within the bounds of what parents in the participatory design study reported would be feasible, as well as a useful test for outcomes based on Anders and Dahl’s (2007) proposed research definition of sleep disturbance.

However, Anders and Dahl do not explicitly deal with how intraindividual sleep variability across nights should factor into definitions of sleep disturbance. In the current project, the focus was on intraindividual variability in sleep duration across the week. The intraindividual variability in children’s sleep and its impact on functioning is not yet well understood. There is preliminary evidence that higher intra-individual variability in sleep duration is associated with some poor outcomes in young children (Bates et al. 2002). However, research in the area of intraindividual sleep variability has only developed in the past few years, and only preliminary results are available (Becker, Sidol, Van Dyk, Epstein, & Beebe, 2017). Other experimental studies on child sleep have dealt with intraindividual variables by constraining children’s sleep schedules and using small sample sizes for maximum control (Berger et al., 2012; Miller et al., 2015; Schumacher et



al., 2017). As well, participants were asked to repeat experimental phases (i.e., sleep restriction) if they were “unsuccessful” initially; that is, if observed duration of sleep restriction did not conform to the degree of sleep restriction in the experimental condition (Schumacher et al., 2017). Such procedures maximize the likelihood of finding differences between sleep restriction and non-restriction conditions. However, they ignore potential issues of sleep variability. Therefore, tightly controlled experimental studies with narrow samples, while valuable for making causal inferences, may not generalize well to the type of sleep that typical preschool children experience. An alternative approach might be to use children’s own baseline-normal sleep variability to determine the amount of sleep restriction.

An ipsative approach to sleep restriction has not, to my knowledge, ever been attempted with children of any age, but it is a relevant consideration for future research to capture larger differences in intraindividual variability between children. Within an ipsative approach, sleep variability is indexed using the within subject standard deviation or a coefficient of variation (Becker et al., 2017). Future research might better account for differences in sleep variability if child participants were assigned to mild or moderate amounts of sleep restriction that represent 1 SD or 2 SD less sleep than usual, computed based on the subject’s own baseline SD. This would allow adjustment for experimental sleep protocols based on the individual child’s sleep variability and could provide more information about the impact of sleep restriction in children who shower greater variability in sleep across as part of their typical sleep pattern.

#### **B) Assessment of sleep in experimental sleep restriction protocols.**

This attempt to design and measure experimental sleep restriction based on proposed research criteria revealed a difficulty in reconciling those criteria (Anders & Dahl, 2007) with the variety of standard sleep measurement procedures available (Acebo et al., 2005). The current findings show how definitions of sleep disruption can vary according to measurement practices. Parents tended to overestimate their children's sleep in diaries relative to actigraph records, a finding that is consistent with previous sleep research in preschool children (Bélanger et al., 2014; Corkum et al., 2001; Iwasaki et al., 2010; Kushnir & Sadeh, 2013; Sadeh, 2008). While parent reports of children's sleep and other measurements are correlated, the association reflects a general parental awareness about how much their child sleeps, rather than precise information: children who sleep less overall have parents who tend to report lower overall averages of sleep in their children. Understandably, parents tend to assume that their children are asleep from the time they are put to bed until the time they rise for the morning, if they are staying quiet.

In the experimental conditions, parents were asked to put their child to bed 20 or 40 minutes later usual, or to wake their child 90 minutes after sleep onset. The time parents put their child to bed during the experimental nights was based on parent perceptions of their child's "usual" bedtime, and how this was reported to researchers. Actigraphy records movement; sleep onset is scored when there are sustained periods of low movement using a validated scoring algorithm (Sadeh, Alster, Urbach, & Lavie, 1989; Sadeh et al., 1991). Parents' records of their children's sleep duration departed from actigraph-scored times. In the current study, the target sleep manipulations did not differ greatly from 30 minutes (i.e., 20 or 40 minutes of sleep restriction, or 20 minutes of sleep fragmentation). Sleep latency for preschoolers is about 24 minutes, but shows wide

variability across children and a tendency to decrease with development (Sahlberg, Lapinleimu, Elovainio, Ronnlund, & Virtanen, 2018). More precise measurement of sleep onset during baseline, and giving parents specific times to put their child to bed might result in sleep restriction being closer to desired durations during experimental manipulations. Actigraph measurement and data transfer technologies have improved. Actigraph data can now be remotely uploaded, rather than requiring in-person visits and device set-up every night. Knowing the precise actigraph-measured sleep duration from each child before imposing sleep restrictions should allow for greater success with experimental restriction protocols. This will be especially helpful for younger children, since sleep is more variable at younger ages (Iglowstein et al. 2003). This method will allow more experimental control over the time of sleep restriction in future experiments.

**(C) Sleep restriction vs sleep optimization.** In children's sleep studies, sleep optimization refers to extending children's sleep opportunity and time, with the goal that they will obtain more sleep relative to their baseline sleep schedule (e.g., Sadeh et al., 2003). Previous experimental sleep studies using within subjects designs with elementary school children have used sleep optimization/extension and restriction. Positive effects on cognitive and emotional functioning have been reported following experiment-imposed sleep extension compared to sleep restriction (Sadeh et al., 2003; Vriend et al., 2013). However, findings comparing sleep optimization to sleep restriction do not necessarily have the same implications as comparing sleep restriction relative to baseline. In fact, both the Sadeh and Vriend studies found significant differences in emotional and cognitive functioning between sleep conditions *only* when optimized and restricted sleep were compared; there were no significant differences between sleep restriction and usual-

baseline sleep duration. The current study did not include a sleep optimization condition. Therefore, we cannot make any inferences about how children's executive functioning performance may have changed if they were assigned to sleep more than their typical schedule. Given that sleep optimization allows for greater separation of average sleep times between experimental groups (including conditions where sleep is extended versus restricted), its use would help future research to detect the effects of sleep on behavioural, emotional, or cognitive outcomes.

**(D) Individual differences in normal sleep and response to sleep restriction.**

Very little has been published regarding individual differences in sleep patterns in preschoolers. It may be the case that children who can sleep on an exceptionally controlled schedule at this age are the exception, rather than the norm. The best available normative data, from the Zurich Longitudinal Studies (Iglowstein et al., 2003), show variability in sleep duration across children is much greater at young ages and appears to narrow with development. For example, the 2nd and 98th percentiles for total 24-hour sleep time at age 2 are 10.8 and 15.6 hours, respectively; whereas at age 5 years, they are 9.5 and 13.3 hours. The limited experimental sleep literature appears to have ignored this variability, which can occur amongst children who do not appear to have sleep problems. It may, however, influence the effects of sleep restriction. It is unlikely that going to bed 90 minutes later would have the same effect on a child with a 45 min standard deviation in sleep duration during a typical week, compared to a child with a 10 min standard deviation. Testing larger samples of children with greater variability in sleep could show more clearly how sleep and sleep restriction affect children in the general population. Future sleep studies should specifically compare daytime outcomes and functioning

between young children who have more variable compared to less variable sleep, to determine the practical significance of sleep variability at young ages. The current study found that during the baseline phase, the average variability in children's sleep duration was 43 minutes. Future research should explore the interaction between sleep variability and sleep restriction. For example, a randomized blocked design with blocks being degree of sleep duration variability could be used.

A second recommendation to study sleep variability would be to create an experimental protocol that imposed increased variability on a random sample of young children and compared outcomes between children experiencing such variability with a control group of children who slept as usual and/or a consistent sleep condition (i.e., keep a strict bed- and rise-times across a week). The impact of variability in sleep schedules at early ages appears to be common, while its effects are relatively unknown, making it an important topic for future study.

## **5.2 Understanding Sleep in Early Childhood: Conceptual Contribution**

This dissertation also contributes to a broader theoretical understanding of sleep in early childhood, as an area of empirical research that has not yet been thoroughly investigated. There is one overarching conceptual issue arising from this dissertation. The major conceptual issue arising from these findings is the need for a greater understanding of what is “normal,” typical, or unproblematic in sleep during early childhood, compared with what is problematic and a potential target for clinical intervention. This conceptual issue is discussed below.

Children's sleeping variability presents a challenge for defining sleep restriction or deprivation in the context of this 10-day study. As noted above, 2-year-olds sleep between 10.8 to 15.6 hours within the 24-hour day, while 5-year-olds sleep between 9.5 to 13.3 hours per day (ranges are 2nd to 98th percentiles: Iglowstein et al., 2003). However, these ranges are understood and reported as variation *between different children* in a longitudinal study. Although there has been a recent growth in research on how much an individual child's sleep varies *within the same child* from night to night at different ages, normative longitudinal data are not yet available (Becker et al., 2017). The data from this dissertation suggest that between-night variability may reflect typical sleep in early childhood. Variability within individual children from day to day has been a relatively understudied feature of sleep in early childhood, but such variability needs to be more explicitly incorporated into our understanding of sleep in development.

A call for better understanding of within child sleep variability implies within it a recommendation for sleep measurement studies of naturally existing variability during the preschool period. From what we know about the greater variability in sleep between children at younger ages, it is not unreasonable to hypothesize that within-subject variation is also high at these ages. However, recommendations for sleep in childhood emphasize the importance of consistency in sleep habits of early childhood, including bedtimes and waking times (Allen, Howlett, Coulombe, & Corkum, 2016; Paruthi et al., 2016; Pesonen et al., 2010). We do not yet understand how variables such as developmental stage and temperament (within-child factors) contributed to intraindividual variability in sleep, compared with parent- and family-level factors that may represent the child's sleeping environment and routines.

Another key point of understanding is the need to differentiate between typical sleep variability that is more likely to be benign and clinically significant sleep variability that indicates a potential problem. Clinical recommendations for parents of children between age 1 and 12 years suggest no more than 30 to 60 minutes variability between children's daily sleep schedules (Allen et al., 2016), which would be within the range of intra-individual variability measured in the present sleep study. Allen and colleagues (2016) reviewed evidence for consistency in sleep schedules and timing; the authors judged that there was a moderate level of empirical support for establishing regular bedtimes, naptimes, and waketimes in children. However, studies in which parents report a consistent bedtime for their children would not necessarily map on to measured variability in sleep via actigraph. The data from the current study reflects this discrepancy: all parents reported that their children had regular bedtimes and waketimes at the time they entered the study, yet actigraphy still revealed variability in sleep of up to 40 minutes across nights. Therefore, the type of variability in sleep reported in studies that have found negative outcomes associated with reported bedtime and waketime variability (Owens, Jones & Nash, 2011) may need a different interpretation compared with variability measured through actigraphy. As Blunden and Galland (2014) indicate in their review of how to define optimal sleep across ages, the many different features of sleep complicate the interpretations of findings across studies. The contexts in which variability is normative versus harmful need to be explored in more detail. Researchers should conduct empirical studies specifically to measure naturally-occurring sleep variability in children to determine a) the ranges of within-child variability that exist within the community at early ages and b) the extent to which different degrees of

variability are associated with negative outcomes, such as daytime behavioural and emotional dysregulation.

### **5.3 Further Research Directions: Measuring Executive Function in Early Child Sleep Restriction Studies.**

The studies included in this dissertation reveal important points to consider for future research. Our results do not support a pathway by which sleep restriction leads to dysregulated behaviour. Nevertheless, a great deal of evidence supports the role of EF as an underlying neurobehavioural indicator of a child's ability to engage in self-regulation of social and emotional behaviour (Denham et al., 2012; Liebermann, Giesbrecht, & Muller, 2007; Zelazo & Cunningham, 2007). There is the possibility that longer sleep restriction would be necessary to demonstrate such an effect. It might also be that sleep restriction would need to occur over a much longer period – perhaps weeks or months – before it would show up as a child sleep problem; however, this would be nearly impossible to test using an experimental design. Furthermore, sleep's regulatory role might act in ways that are not detectable using the types of neurobehavioural outcome measures that we included. One problem which we encountered was the presence of ceiling effects in our Go/No-Go inhibitory measure of EF, where most children performed well. Despite designing this task using age-appropriate timing for the presentation of stimuli (Simpson & Riggs, 2006), the presence of ceiling effects suggests that many of our child participants did not find the task challenging. Matching EF tasks carefully to the ages of children for which they have been previously used could yield more informative and specific data about how EF and sleep are related during this age period. Due to the relatively rapid changes in EF during the period of preschool development, future researchers may consider restricting the age range of participants



included in sleep restriction studies. Another possible avenue would be to include a broader range of ages, but to vary the difficulty of EF performance measures within the same study. Additional EF performance measures are now available that have developed and validated for use with preschool children (Garon et al., 2014). Newer EF performance measures that include continuous scales of measurement (rather than pass/fail measures with dichotomous outcomes) would be the most useful to include in further investigations of sleep restriction, as these could detect more subtle changes in EF as the result of sleep changes.

#### **5.4 Sleep Measurement in Preschool Children and Development**

Perhaps one reason that the preschool population has been understudied when it comes to sleep is that they are undergoing a natural developmental transition at different rates: the preschool period is the time when daytime napping gradually diminishes. Therefore, protocols designed to measure preschool sleep, must account for children sleeping during the day. This presents a great challenge because it is typical for preschool children to not nap every day, leading to major differences in the timing of sleep over successive 24-hour periods. Furthermore, naps on different days make it more complicated to restrict sleep in a systematic manner across participants. Inclusion of daytime napping is essential when studying this age group since it is developmentally typical for most children of this age. Many (87%) 3-year-olds nap, while far fewer children are napping (8%) at age 5 (Iglowstein et al., 2003). In studies with older cohorts, participants are typically instructed not to nap during experimental protocols. This helps control sleep duration and timing across subjects, which is ideal for experimental purposes. However, this is not ideal for preschoolers who nap as part of their daily life. In

effect, the elimination of a regular nap creates sleep restriction for children who are napping occasionally, placing additional restrictions on their typical sleep schedule.

The sleep restriction study from this dissertation attempted to include as many children as possible, which include those who napped occasionally during the day, those who never napped and those who always napped. For future researchers who wish to maximize control over sleep schedules for a sleep restriction protocol, it makes sense to include only children who nap regularly during the day (Berger et al., 2012). It is also possible to restrict a sample preschool sample to children who do not nap. Although more complicated to implement sleep restriction among children who nap on some days and not others during a typical week, such data would be important to provide a fuller picture of sleep during this age period, especially because the time frame for giving up naps appears to occur over a span of 2-3 years for the majority of the population (Iglowstein et al., 2003). A possible method for future researchers that might allow for adequate sleep restriction without too many changes for occasional daytime nappers would be to implement a sleep restriction phase over the course of a week, rather than 3 days. This longer period would permit children to experience sleep restriction on days when they had naps as well as on days that they did not and hopefully would minimize the degree to which those who napped more often (e.g., 5/7 days per week) experienced more sleep restriction compared with those who napped less often (e.g., 2/7 days per week). In order to implement such a design successfully, it would be essential for researchers to communicate closely with parents. Daily contacts with parent participants and review of the sleep data collected would help to ensure that the child's usual napping and nighttime

sleeping schedule was continuing as expected, along with any experimentally assigned changes in sleep.

The methods of sleep measurement chose for this experiment also deserve some comment. A practical reason for choosing actigraphy and sleep diary (versus videosomnography) to obtain objective sleep measurements was the convenience and relative non-intrusiveness of actigraphs for 24-hour sleep / wake recording. Preschool children often nap in a setting different from that of night sleep, whether they are cared for by a different family member or in a formal daycare setting. As the actigraph travels with the child, and a sleep diary can more or less do so as well, actigraphy is likely the most feasible way of measuring sleep across the 24-hour period in this population. That said, other types of sleep measurement can yield information that the actigraph does not, such as sleep fragmentation (O'Driscoll, Foster, Davey, Nizon, & Home, 2010; Sitnick et al., 2008). Using a videosomnography or electroencephalography (EEG) is most feasible with smaller samples. Much remains unknown about the direct impact of sleep disruption in children between ages 3 and 5 years, so more sleep restriction studies with this age group that use EEG or videosomography would be valuable contributions.

### **5.5 Conclusion**

There continues to be a need for empirical evidence of the role of sleep in child development. The developmental functions of sleep in early childhood may be substantively different from those in later childhood, adolescence and adulthood, especially since important neural reorganization occurs over this period (Casey, Galvan, & Hare, 2005; Feinberg, Thode, Chugani, & March, 1990; Shaw et al., 2008). This research provides an important contribution to the existing literature due to its inclusion

of children between the ages of 3 and 5 years in an experimental paradigm that manipulates nighttime sleep, while also accounting for sleep obtained during naps. As conclusions about sleep's causal contribution to neurobehavioural functions cannot simply be inferred from research on older populations, this research provides a framework for how to conduct a study with a sample of younger children. The ubiquity and drive for sleep strongly suggest that sleep plays a role in brain development. Despite sleep's apparent importance in early life, the specific functions of sleep in the context of child development remain elusive.

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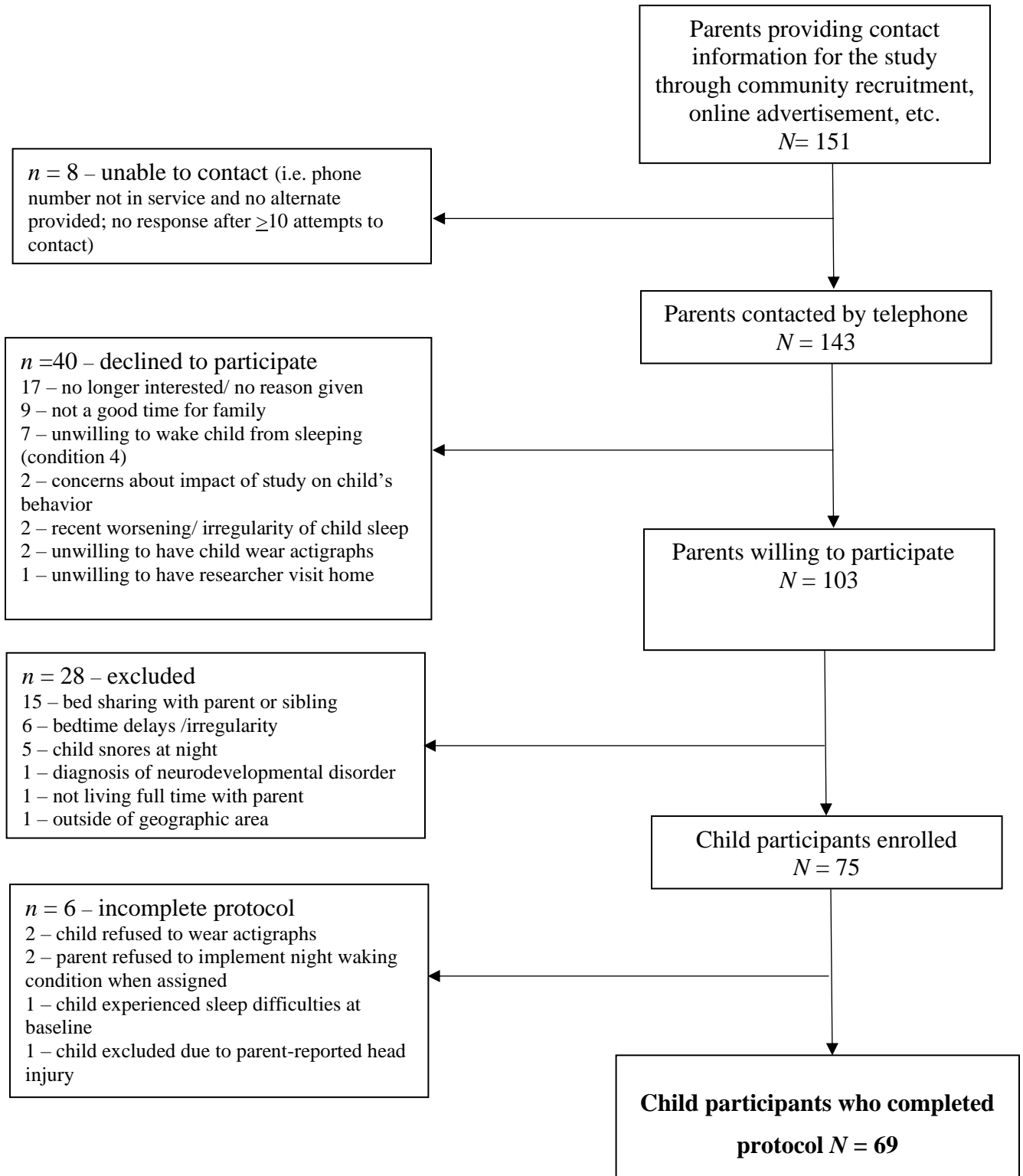
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## Appendix A



**Curriculum Vitae**  
**Kathryn Anne Turnbull**

**1. Education**

**University of Western Ontario**

London, Ontario, Canada

**Degree:** Master of Science (M.Sc.)

**Program:** Psychology

Oct. 23, 2009

**Dalhousie University & The University of King's College**

Halifax, Nova Scotia, Canada

**Degree:** Bachelor of Science (B.Sc.)

**Program:** Psychology (Honours)

May 18, 2006

**2. Predoctoral Clinical Training Experience**

**Vanier Children's Services**

Jan. 2016-

**Supervisors:** Dr. Jeffrey Carter, C. Psych; Dr. Esther Goldberg,

Aug. 2016

C. Psych

**Service Description:** Children with complex trauma in residential care, community consultations.

**British Columbia Psychology Residency Program**

Sept. 2014 -

**Ministry of Child and Family Development**

Aug. 2015

**Supervisors:** Dr. Joanne Crandall, R. Psych; Dr. Susan Hackett, R. Psych; Dr. Patricia Rycroft, R. Psych

**Service Description:** Child and adolescent mood and anxiety disorders (individual and group interventions), supportive community parenting group for at-risk parents (Aboriginal Friendship Centre), community consultation and supportive play therapy for complex childhood trauma, child and adolescent psychological assessments.

**Canadian Mental Health Association – Wait List Clinic**

Feb. 2014-

**Supervisors:** Dr. Felicia Otchet, C. Psych; Dr. William Newby,

Jul. 2014

C. Psych; Dr. Erica Gold, C. Psych

**Service Description:** Program evaluation data collection, adult mental health counselling (co-supervisor of trainee counselors).

**Child and Parent Resource Institute**

Sept. 2013-

**Supervisor:** Dr. Louise LaRose, C. Psych.

Apr. 2014

**Service Description:** Autism Spectrum Disorder screening and interventions.

**London Health Sciences Centre, Pediatric Psychology**

Mar. 2013-

**Supervisor:** Dr. Erica Gold, C. Psych

Aug. 2013

**Service Description:** Child and adolescent health psychology (intervention).

**Thames Valley District School Board** Sept. 2012-  
**Supervisor:** Dr. Barbara Richardson, C. Psych Jun. 2013

**Service Description:** Adolescent psychotherapy and counseling, school team consultation, psychological assessment (Community Living Program)

**Child and Parent Resource Institute** Jan. 2012-  
**Supervisors:** Dr. Gani Braimoh, C. Psych; Dr. B. Duncan Aug. 2012

McKinlay, C. Psych; Dr. Jeffrey St. Pierre, C. Psych; Dr. Jennifer Crotagino, C. Psych; Ms. Jillian Schuster, Psychology Resident

**Service Description:** Dual diagnosis residential intervention, psychological assessment, group cognitive-behavioural therapy for children with parents.

**Private Practice** Apr. 2011-  
**Supervisor:** Dr. William Newby, C. Psych Dec. 2011

**Service Description:** Adult individual psychotherapy.

**Thames Valley District School Board** Sept. 2010-  
**Supervisors:** Dr. Barrie Evans, C. Psych; Dr. Janice Kurita, Sept. 2011  
 C. Psych

**Service Description:** Adolescent counseling, psychological and learning assessment.

**Madame Vanier Children's Services** May 2010-  
**Supervisor:** Dr. Jeffrey Carter, C. Psych, Ms. Marie-Eve Mar. 2011  
 Hubertise, Psychology Resident

**Service Description:** Childhood psychological assessment, brief family therapy.

**Student Development Centre, University of Western Ontario** Sept. 2009-  
**Supervisor:** Dr. Kathryn Dance, C. Psych Apr. 2010

**Service Description:** Adult psychotherapy.

**London Health Sciences Centre, Hospital Epilepsy Unit** Jan. 2009-  
**Supervisors:** Dr. Paul Derry, C. Psych; Dr. Felicia Otchet, C. Jul. 2009  
 Psych; Ms. Damini Malhotra, Psychology Resident

**Service Description:** Adult Health Psychological Assessment.

### 3. Teaching

**King's University College, Psychology Department** Sept. 2020-  
 London, Ontario Dec. 2020

**Position:** Part-Time Faculty

**Course Title:** Child Psychopathology 3320F (Online)

<p><b>The University of Western Ontario, Psychology Department</b>  London, Ontario  <b>Position:</b> Instructor  <b>Course Titles:</b> Abnormal Psychology 2310A  Child Development 2040B (Distance Studies)</p>	<p>Sept. 2018-  Apr. 2019</p>
<p><b>The University of Western Ontario, Psychology Department</b>  London, Ontario  <b>Position:</b> Co-Instructor with Dr. G. J. Reid (Distance Studies)  <b>Course Title:</b> Introduction to Clinical Psychology 3301F</p>	<p>May 2014-  Jul 2014</p>
<p><b>The University of Western Ontario, Psychology Department</b>  London, Ontario  <b>Position:</b> Teaching Assistant (Instructor: Dr. R. A. Martin)  <b>Course Title:</b> Abnormal Psychology 2310A/B</p>	<p>Nov 2013-  Apr 2014</p>
<p><b>The University of Western Ontario, Psychology Department</b>  London, Ontario  <b>Position:</b> Undergraduate Thesis Co-Supervisor with Dr. G. J. Reid  <b>Student:</b> Ms. Jessica Danilewicz</p>	<p>Sept 2013-  Apr 2014</p>
<p><b>The University of Western Ontario, Psychology Department</b>  London, Ontario  <b>Position:</b> Teaching Assistant (Instructor: Dr. P. Hoaken)  <b>Course Title:</b> Clinical Psychology 3310A</p>	<p>Sept 2012-  Dec 2012</p>
<p><b>The University of Western Ontario, Psychology Department</b>  London, Ontario  <b>Position:</b> Undergraduate Thesis Co-Supervisor with Dr. G. J. Reid  <b>Student:</b> Ms. Kirsten Maich</p>	<p>Sept 2012-  Apr 2013</p>
<p><b>The University of Western Ontario, Psychology Department</b>  London, Ontario  <b>Position:</b> Teaching Assistant 2820E (Instructor: Dr. R. Hinson)  <b>Course Title:</b> Research and Statistical Methods in Psychology  20820E</p>	<p>Sept 2010-Mar  2011  Sept 2009-Mar  2010  Sept 2006-Mar  2007</p>
<p><b>The University of Western Ontario, Psychology Department</b>  London, Ontario  <b>Position:</b> Teaching Assistant 281 (Instructor: Dr. P. Vernon)  <b>Course Title:</b> Statistics for Psychology 281</p>	<p>Sept 2007-  Feb 2008</p>

#### 4. Peer-Reviewed Publications



**Turnbull, K.,** Reid, G. J., & Morton, J. B. (2013). Behavioral sleep problems and their potential impact on developing executive function in children. *Sleep, 36*, 1077-1084.

**Turnbull, K. A.,** Deacon, S. H., & Kay-Raining Bird, E. (2011). Mastering inflectional suffixes: A longitudinal study of beginning writers' spellings. *Journal of Child Language 38*, 533-553.

## 5. Academic Conference Presentations

**Turnbull, K.,** Reid, G. J., & Morton, J. B. (2013, June). Behavioural sleep problems and their potential impact on developing executive function in children. Poster presented at the Canadian Psychological Association Conference, Quebec City, Quebec.

**Turnbull, K.,** & Reid, G. J. (2012, June). *Parent perceptions of sleep disruption in preschoolers: A qualitative study.* Poster presented at the Canadian Psychological Association Conference, Halifax, Nova Scotia.

Reid, G. J. & **Turnbull, K.** (2008, March). *The effect of routines on bedtime resistance and night waking among preschool-age children.* Poster presented at the Annual Pediatric Sleep Medicine Conference, Amelia Island, Florida.

## 6. Other Publications

Reid, G. J., & **Turnbull, K.A.,** & Currie, M. (forthcoming). *Sleep Disturbance Collaborative Action Plan for Youth Justice Custodial Facilities.* In S.L. Stewart, K. Arbeau, J.N. Morris, K. Berg, M. Björkgren, A. Declercq, et al. Collaborative Action Plans (CAPs) for use with the interRAI Youth Justice Custodial Facilities (YJCF) Instrument. Research Version 1 Standard Edition Washington, DC: interRAI.

Reid, G. J., & **Turnbull, K.A.,** & Currie, M. (2015). *Sleep Disturbance Collaborative Action Plan.* In S.L. Stewart, L.A. Theall, J.N. Morris, K. Berg, M. Björkgren, A. Declercq, et al. interRAI Child and Youth Mental Health Collaborative Action Plans (CAPs): For Use with the Child and Youth Mental Health Assessment Instrument. Version 9.3. Washington, DC: interRAI.

## 7. Research Projects and Activities (Graduate)

**Research Trainee: Better Nights, Better Days Sleep Project**  
National Training Initiative supported by Canadian Institutes  
of Health Research (CIHR) Team Grant

Jan. 2012-  
Aug. 2015

- Research Project:** *Brief Sleep Restriction and Executive Function Performance in Preschool Children* (Dissertation) Jan. 2011-Aug. 2014  
**Supervisor:** Dr. Graham Reid  
**Collaborator:** Dr. J. Bruce Morton
- Research Project:** *Parent Perceptions of Sleep Disruption in Children: A Participatory Design* (Dissertation) Jun. 2010-Jun. 2012  
**Supervisor:** Dr. Graham Reid
- Research Project:** *The Relationship of Parenting Practices to Positive Child Routines and their Effects on Common Sleep Problems in Young Children* (Master's thesis) Nov.2006-Jun. 2009  
**Supervisor:** Dr. Graham Reid

## 8. Grants

- Funding Agency:** Lawson Health Research Institute \$14,083  
**Project Title:** Brief Sleep Restriction and Neurobehavioural Outcomes in Preschool Children  
**Investigators:** Reid, G. J. (PI), Turnbull, K. A. (Co-I), Morton, J. B. (Co-I)  
**Dates:** January 2011-April 2013
- Funding Agency:** Children's Health Research Institute \$7,500  
**Project Title:** Brief Sleep Restriction and Neurobehavioural Outcomes in Preschool Children: Exploring Between and Within Subjects Effects  
**Investigators:** Reid, G. J. (PI), Turnbull, K. A. (Co-I), Morton, J. B. (Co-I)  
**Dates:** July 2011-June 2014

## 9. Graduate Awards and Scholarships

- Health Professional Student Research Award** 2013  
Canadian Institutes of Health Research
- Frederick Banting and Charles Best Canadian Graduate Scholarship** 2011-2013  
Canadian Institutes of Health Research
- Health Professional Student Research Award** 2010  
Canadian Institutes of Health Research
- Quality of Life Graduate Student Support Bursary** 2009-2010  
Children's Health Research Institute (CHRI)
- Ontario Graduate Scholarship** 2007-2008
- Canadian Graduate Scholarship** 2006-2007  
Social Sciences and Humanities Research Council