Pilot Study: The association between sleep and Theory of Mind in school aged children

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Abstract

Theory of Mind (ToM) is defined as the ability to infer a range of internal mental states of others, including beliefs, intentions, desires, and emotions. ToM is a positive predictor of children’s ability to socialize effectively with peers. ToM impairments are associated with peer rejection and various psychiatric disorders. Executive functioning (EF) and emotional information processing are essential for effective use of ToM. Previous studies have found poor sleep negatively impacts both. However, the relationship between sleep, EF, and emotional information processing and ToM has not been studied. The objective of this pilot study was to examine whether ToM is associated with sleep in school aged children. It was hypothesized that shorter sleep duration and lower sleep efficiency would impair emotional information processing abilities, and in turn be associated with poorer ToM. It was further hypothesized that sleep would moderate the association between EF and ToM, so that children with shorter sleep duration and lower sleep efficiency would have poorer EF and poorer ToM and children with longer sleep duration and higher sleep efficiency would have better EF and better ToM. 31 children aged 8 – 11 years participated in the study. Their sleep duration and efficiency were monitored for 5 nights at home using actigraphy. Next, participants completed two ToM tasks: 1) The Reading the Eyes in the Mind Task, measuring affective ToM, which requires emotional information processing of facial stimuli and; 2) The Faux Pas Recognition Task, measuring affective and cognitive ToM by testing participants understanding of appropriate social situations through inferring the feelings and intentions other’s. Children’s EF was measured using the Continuous Performance Task and the Conners Parent Short Form. Multiple regression analyses revealed that there were no significant associations between sleep duration or efficiency and ToM performance on either task. Furthermore, sleep did not moderate the relationship between EF and
ToM. This pilot study revealed no association between sleep and ToM performance in school aged children. Future studies should continue to examine this relationship with a larger, more diverse sample size, while using a variety of different tasks that tap into ToM ability.

**Keywords:** Theory of Mind, sleep, executive functions, emotion information processing, youth
Résumé

La théorie de l’esprit (TdE) est définie comme la capacité de déduire une gamme d’états mentaux internes dont des croyances, des intentions, des désirs, et des émotions. La TdE a été prouvée comme un prédicteur positif sur la capacité des enfants de socialiser efficacement avec leurs pairs. La déficience de la TdE est associée avec du rejet de la part des pairs et des troubles psychiatriques divers. Le fonctionnement exécutif (FE) et la gestion des émotions sont essentiels pour l’utilisation efficace de la TdE. Les études précédentes ont trouvé qu’un sommeil perturbé a un impact négatif sur les deux. Cependant, la relation entre le sommeil, FE, la gestion des émotions, et le développement de la TdE n’a jamais été examinée. L’objectif de ce projet pilote était d’examiner si la TdE est associée avec le sommeil des enfants de l’âge scolaire. Il était supposé que un sommeil ayant une durée plus courte et de faible efficacité serait associé avec une TdE inachevée. Il était attendu davantage que le sommeil modérait l’association entre le FE et la TdE pour que des enfants ayant un sommeil de mauvaise qualité aurait eu un FE et une TdE faibles et ceux avec un meilleur sommeil aurait eu un meilleur FE et TdE. 31 enfants l’âge de 8 à 11 ans ont participé dans l’étude. La durée et l’efficacité de leur sommeil a été surveillé pendant 5 nuits à domicile avec l’actimétrie. Ensuite, les participants ont complété deux tests de la TdE : 1) le test « Reading the Eyes in the Mind », mésure la TdE affective, qui besoin la gestion des émotions des stimuli faciaux, et 2) le test « Faux Pas Recognition », mésure la TdE affective et cognitive, par testant la compréhension des participants sur les situations sociales appropriées en déduisant les sentiments et les intentions des autres. Le FE des enfants était mesuré par le test « Continuous Performance » et le « Conners Parent Short Form ». Plusieurs analyses de régression ont démontré qu’il n’avait pas d’associations significatives entre la durée du sommeil ni l’efficacité et la performance de TdE sur chacun des testes. De plus, le sommeil n’a pas
régularisé la relation entre le FE et la TdE. Ce projet pilot a démontré aucune association entre le sommeil et la performance de la TdE parmi les enfants de l’âge scolaire. D’autres études supplémentaires devraient continuer d’examiner cette relation avec une échantillon plus divers et nombreux, tandis que l’utilisation des tests différentes varies qui identifie la capacité de la TdE.

**Mots clés:** Théorie d’esprit, sommeil, fonctionnement exécutif, gestion d’informations émotives, jeunes
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Contributions

As first author, I contributed to each part of preparing and conducting this study. I created the conceptual framework and study design with the guidance of Dr. Reut Gruber. I prepared and programmed all measures used. I recruited participants, conducted assessments and scored data with the assistance of Shannon Dourin, Alexa Brown, and Evelyn Kim. Arturo Sebastian double checked all actigraphy sleep data. Under the supervision and guidance of Dr. Reut Gruber, I interpreted data analyses and wrote the current manuscript.
Pilot study: The association between sleep and theory of mind in school-aged children

ToM is defined as the ability to infer a range of internal mental states including beliefs, intentions, desire, and emotions (Premack and Woodruff, 1978; Wellman, 1990). It is central to the development of social cognition in children, referring to the psychological processes needed for an individual to integrate and be a part of a social group (Frith, 2008). Children’s capacity to successfully use ToM has been shown to be a positive predictor of their ability to socialize effectively with peers (Peterson, Slaughter, Moore and Wellman, 2016; Watson, Nixon, Wilson and Capage, 1999) and demonstrate pro-social behaviours, including the expression of cooperation and helping (Imuta et al., 2016). ToM impairments are associated with peer rejection (Banerjee et al., 2011; Slaughter, Imuta, Peterson, and Henry, 2015) and various psychiatric disorders, such as depression and anxiety (Bora and Berk, 2016; Lee, Harkness, Sabbagh and Jacobson, 2005; Hezel and McNally, 2014), and neuro-developmental disorders, like autism (Cohen, 2000).

Very little is known about the factors or mechanisms that influence the development of successful ToM in school aged children. Previous studies have found poor sleep negatively impacts executive functioning and is associated with impaired emotional processing. Both of these impairments represent deficits in ToM. However, the relationship between sleep and ToM development has not been studied. This pilot study aimed to examine the associations between sleep duration and efficiency and affective and cognitive ToM in school aged children. Furthermore, we aimed to examine if sleep duration and efficiency moderates the relationship between EF and ToM ability.

The objective of this pilot study was to examine whether ToM is associated with sleep in school aged children. It was hypothesized that longer sleep duration and higher sleep efficiency
would be associated with better ToM. It was further expected that sleep would moderate the
association between executive functions (EF) and ToM, so that children with better sleep would
have better EF and better ToM and children with poor sleep would have poorer EF and poorer
ToM. The rationale for the proposed pilot study is that a better understanding of the association
between sleep and ToM will lead to a future experimental study, allowing us to determine if
there is a causal association between sleep and ToM. This information can then eventually be
applied for forming the basis of developing innovative approaches to support children with
dysfunctional ToM and improve their future social cognitive development.

2.0 Theory of Mind (ToM)
ToM is defined as the ability to infer other’s internal mental states including beliefs, intentions,
desires, and emotions (Premack and Woodruff, 1978; Wellman, 1990). ToM emerges around the
age of 4 with the mastery of first order false belief tasks, signifying their awareness that
individuals can hold beliefs that contrast with reality and their own beliefs (Wimmer and Perner,
1983; Perner, 1991; Wellman, Cross and Watson, 2001). ToM has been recognized as a pivotal
milestone in social development for children across cultures (Frith and Frith 1999; Hughes et al.,
2014; Sabbagh et al., 2006). Children develop more complex “higher order” ToM abilities as
they age (Miller, 2009). This includes successfully completing second order false-belief tasks,
demonstrating an understanding of another person’s thoughts about a third person(s) (Perner &
Wimmer, 1985). For instance, a child demonstrating second-order false belief will predict that
his/her friend will behave differently in a situation, if their friend does not have the same new
information as someone else (e.g., if the teacher changes the class location and the friend has not
been informed, they will go to their regular class room, but the rest of the class who has been
Recognizing that two people can have different understandings of the same situation, and that someone’s underlying understanding might be different from what is apparent in reality (Perner, 1991) is implicated in several everyday tasks. These tasks include detecting deception and others emotions, and understanding the use of non-literal language (e.g., metaphors and sarcasm) (Happe, 2003), all of which are critical to social skills. Social skills are broadly defined as the ability to interact with other’s appropriately and effectively (Segrin 2000; Spitzberg and Cupach, 1989). Such ToM skills, like detecting if someone is lying to you or understanding if someone is upset and why, is crucial to knowing how to appropriately engage in social situations.

ToM ability is a predictor of social skills (Peterson, Slaughter, Moore and Wellman, 2015), as well as pro-social behavior (Caputi, Leece, Pagnin, and Banerjee, 2011; Imuta et al., 2016), and emotional regulation (Beaurain and Nader-Grosbois, 2013; Riggs, Greenberg, Kusche, & Pentz, 2006). Impairments in ToM are associated with higher rates of peer rejection (Banerjee et al., 2011; Slaughter, Imuta, Peterson, and Henry, 2015), aggressive behavior (Harvey et al., 2001; Renouf et al., 2010) and diverse psychiatric (Bora and Berk, 2016; Lee, Harkness, Sabbagh and Jacobson, 2005; Hezel and McNally, 2014) and neuro-developmental disorders, like autism (Cohen, 2000).

ToM has cognitive and affective components (Kalbe et al., 2010; Shamay-Tsoory, Shur, Barcai-Goodman and Levkovitz, 2007; Abu-Akel and Shamay-Tsoory, 2011). Cognitive ToM refers to inferences about other’s beliefs and intentions, while affective ToM, refers to inference about other’s emotions and feelings. The distinction between affective and cognitive components of ToM has been supported by studies showing performance can vary among ToM tasks and
impairments of one ToM component may not correspond to impairments of the other (e.g., Bottiroli et al., 2016, Roca et al., 2010; Sebastian et al., 2012; Shamay-Tsoory & Aharon-Peretz, 2007; Shamay-Tsoory, Tibi-Elhanany, and Aharon-Peretz, 2006; Van Overwalle, 2009).

Neuroimaging studies support the existence of a ‘core neural network’ for ToM, which includes the medial prefrontal cortex and the bilateral posterior temporo-parietal junction. This network has been proposed, because these neural areas are activated during all ToM tasks, irrespective of modality or stimuli, as they require thinking about the mental states of other persons (Frith and Frith, 2006). Within this network, distinctions between affective and cognitive ToM has been made (For a comprehensive review see: Abu-Akel and Shamay-Tsoory, 2011 and Schurz et al., 2014). Affective ToM engages the ventral medial prefrontal cortex, inferior lateral frontal cortex, ventral striatum, ventral temporal pole, ventral anterior cingulate cortex, orbitofrontal cortex, and the amygdala (Abu-Akel and Shamay-Tsoory, 2011; Schurz et al., 2014). Cognitive ToM recruits the dorsal medial prefrontal cortex, dorsal lateral prefrontal cortex, dorsal striatum, dorsal temporal lobe and the dorsal anterior cingulate cortex (Abu-Akel and Shamay-Tsoory, 2011; Schurz et al., 2014).

Tasks used to measure affective and cognitive ToM vary in types of stimuli and modality. They include situational narrative tasks and picture identification formats. The Reading the Mind in the Eyes Task (RMET; Baron-Cohen et al., 1997, 2001) assesses affective ToM. It requires the identification of a word that best describes how a person is thinking or feeling based on photographs presented to them of the eye regions of human faces. It is dependent on emotional facial processing. The neural pathways involved in affective facial recognition and emotional information processing that include the amygdala and fusiform gyriare, are implicated in the performance of this task (Adolphs, 2002; Abu-Akel and Shamay-Tsoory, 2011; Yoo et al.,
Affective ToM tasks also require the ability to detect and regulate one’s own emotions. Emotional regulation refers to the intrinsic and extrinsic processes responsible for monitoring, evaluating and modifying one’s own emotional reactions (Thompson, 1994). This ability enables a person to make inferences based on the feelings and emotions of other’s, while having an awareness of their own differing emotional state and regulating it appropriately in a situation.

The Faux Pas Recognition Task (FPR; Stone, Baron-Cohen and Knight, 1998) measures both cognitive and affective ToM abilities. It presents a story to a participant who is asked to determine if a character has said something socially inappropriate “faux pas” that would insult of hurt someone’s feelings (affective component), and asked if the “faux pas” was intended to hurt the listener’s feelings, and to determine the character’s intention to cause harm (cognitive component).

Although neural mechanisms underlying ToM have been characterized, behavioural and psychological factors that may influence or interact with these networks are still poorly understood. The most prevalent explanatory psychological mechanism put forth to account for ToM performance is executive functioning.

2.1 Executive functioning and Theory of Mind (Figure 1)

Executive functioning (EF) is an umbrella term that describes the cognitive processes that enable one to engage in deliberate, goal-directed thought and action (Carlson, Zelazo and Faja, 2013; Diamond, 2013). The components of EF include: working memory, inhibitory control and cognitive flexibility (Carlson, Zelazo & Faja, 2013; Friedman & Miyake, 2004; Miyake et al., 2000). Working memory is the capacity to retain information short-term to guide future actions (Carlson, Zelazo and Faja, 2013; Diamond 2013); Inhibitory control is the ability to override
prepotent responses, which involves being able to control one’s attention, behaviours, and/or emotions (Diamond, 2013); Cognitive flexibility (also known as ‘cognitive shifting’ or ‘task shifting’) refers to the ability to shift between tasks and adapt to new information (Carlson, Zelazo and Faja, 2013). Moderate to strong associations have been found between EF subcomponents and ToM in childhood (Devine and Hughes, 2014). The two constructs – EF and ToM- are reported to be dependent on the prefrontal cortex, (Fuster, 2008) and they both develop in a similar fashion from early to middle childhood (Davidson, Amso, Anderson and Diamond, 2006; Apperly, Warren, Andrews, Grant and Todd, 2011, Devine and Hughes, 2013).

EF and its subcomponents have been related to subcomponents of ToM (Apperly, Warren, Andrews, Grant and Todd, 2011). Inhibitory control is needed to inhibit salient knowledge of current reality and one’s own emotions, beliefs or intentions, in order to successfully respond to other’s mental states needed for both cognitive and affective ToM (Carlson and Moses, 2001). Cognitive flexibility is needed in order to shift between perspectives and mental states of other’s and oneself. Lastly, the capacity to actively retain multiple perspectives and information as one processes information requires working memory capacity. Collectively, EF abilities including inhibitory control, cognitive flexibility and working memory are simultaneously needed to successfully detect the mental states of others ToM.

Although the majority of research connecting EF and ToM has been conducted in preschool children, there is evidence to suggest that this link extends into school age (Austin, Groppe, and Elsner, 2014). For instance, cognitive flexibility in school age children predicts performance on social understanding tasks requiring affective and cognitive ToM abilities (Bock, Gallaway and Hund, 2015). Cognitive flexibility, along with working memory, have also been shown to longitudinally predict affective and cognitive ToM ability on social scenario tasks in.
school aged children (Austin, Groppe, and Elsner, 2014). While very strong associations exist between inhibitory control and ToM in pre-school years (Carlson & Moses, 2001; Perner & Lang, 2000; Sabbagh et al., 2006), very little is known about this relationship as children develop.

3. Sleep

3.1 Sleep and EF (Figure 2)

According to the two process model, sleep timing and duration is regulated by two distinct, yet interacting biological processes; 1) sleep-wake homeostasis (“process s”) and 2) the circadian rhythm (“process c”) (Borbély 1982). A homeostatic sleep drive (i.e., the biological need for sleep) accumulates the longer a person is awake, causing pressure to fall asleep. The circadian rhythm controls the timing of sleep. It’s an oscillatory rhythm that fluctuates with an approximate daily cycle of 24 hours. The circadian rhythm is driven by an internal pacemaker, “biological clock,” located in the superchiasmatic nucleus. External environmental stimuli known as “zeitgerbers,” which includes light-dark cycles and temperature, influence circadian rhythms. Expert consensus recommends school children aged 6-12 years, sleep a duration of 9 to 11 hours a night consistently to promote optimal health outcomes (Hishkowitz, 2015; Paruthi et al., 2016; Tremblay et al., 2016).

Insufficient and inadequate sleep is associated with poor executive functioning (Beebe et al., 2004; Bourke et al., 2011; Dahl, 1996; Friedman, Corley, Hewitt and Wright, 2009; Gregory, Caspi, Moffitt and Poulton, 2009; Nelson et al., 2015; Nilsson et al., 2005, Taveras et al., 2017). Insufficient sleep refers to getting less sleep than needed (Owens, 2014). Inadequate sleep refers to low sleep efficiency, defined as the percent of time in bed spent sleeping (Ohayon et al., 2017). Neuroimaging studies reveal that sleep deprivation negatively disrupts the prefrontal
cortex, a neural system central to EF’s (Durmer & Dinges, 2005; Fuster, 2008). Individuals with insomnia who experience poor sleep, characterized by frequent night awakenings, low sleep efficiency, troubles falling asleep at bedtime and early morning awakenings (Edinger et al., 2004; Morin and Benca, 2012), are shown to have altered connectivity in the frontostriatal networks (Lu et al., 2017). Impaired frontostriatal connections are associated with EF deficits (Riley, Moore, Cramer, and Lin, 2011).

Shortened sleep duration and low sleep efficiency are associated with impaired inhibitory control abilities in youth and adults (Chuah et al., 2006; Drummond, Paulus, and Tapert et al., 2006; Gruber et al., 2011; Maski and Kothare, 2003; Molfese et al., 2013; Sadeh, Gruber and Raviv, 2002). Behavioural tasks measuring the ability to suppress prepotent responses, known as inhibitory control, are negatively impacted by one to two nights of moderate sleep deprivation in adults (Chuah et al., 2006; Drummond, Paulus, and Tapert et al., 2006). After sleep deprivation adult’s performance on the Go/No-Go Task, a computerized task whereby inhibitory control is measured by participant’s ability to withhold responses to a known target, significantly deteriorates (Chuah et al., 2006; Drummond, Paulus, and Tapert et al., 2006). Similarly, six nights of moderate sleep deprivation, measured using actigraphy in typically developing school aged children and children diagnosed with ADHD, is shown to significantly impair their performance on the Continuous Performance Task (CPT; Gruber et al., 2011). The CPT measures impulsivity and inhibitory control (Halperin et al., 1991) by testing participant’s ability to suppress their responses to a known target (i.e., the letter X), just like the Go/No-Go Task. One week of moderate sleep deprivation also alters brain activity measured by event-related potentials, in school aged children compared to non-sleep deprived school children performing the same inhibitory control task (Molfese et al., 2013).
In addition to sleep deprivation, extending sleep duration by less than an hour, has been found to improve inhibitory control abilities in children (Sadeh et al., 2003). The following experimental study provides support for a casual association between sleep and inhibitory control in youth (Sadeh et al., 2003). School-aged children were randomized to a sleep extension or sleep deprivation group (Sadeh et al., 2003). Children in the sleep extension group, who slept an average of 35 minutes longer than their sleep deprived peers, performed significantly better on the CPT.

Typically developing children with low sleep efficiency, measured with actigraphy, are also shown to perform poorly on the CPT, compared to peers with higher sleep efficiency (Sadeh, Gruber, and Raviv, 2002). Taken together, these results provide strong support/evidence for the impact sleep has on inhibitory control ability.

The capacity to retain working memory is also affected by insufficient and poor quality sleep in youth (Gruber et al., 2012; Kopasz et al., 2010; Sadeh et al., 2003; Sadeh, Gruber, and Raviv, 2002; Steenari et al., 2003; Vriend et al., 2013). After going to bed one hour later than usual for four nights, school age children’s working memory ability deteriorated compared to when they went to bed an hour earlier than their regular sleep schedule (Vriend et al., 2013). Two nights of actigraphy and one night of polysomnography (a gold standard biophysiological sleep measure, monitoring EEG signals in the brain and other physiological movement during sleep) data of school aged children also revealed lower sleep duration was associated with poorer working memory ability compared to peers with higher sleep duration, as reported by their teachers on the revised Conners Teacher Rating Scale (Gruber et al., 2012). Sadeh et al., (2003) found that extending school aged children’s sleep duration, monitored by actigraphy, significantly improved their performance of the Digital Span task. Low sleep efficiency in
children, measured for 72 hours using actigraphy, is also shown to be associated with poor auditory and visual working memory performance on the n-back task (Steenari et al., 2003). Overall, evidence to date demonstrates short sleep duration and low sleep efficiency significantly impairs working memory ability.

Cognitive flexibility in youth is shown to be affected by sleep duration (Dewald-Kaufmann, Oort and Meijer, 2013), however limited research exists and its relation to sleep efficiency is unknown. In adolescents, two weeks of extending sleep duration 5 minutes a night, measured using actigraphy, was found to have positive performance effects on the Divided Attention task (Dewald-Kaufmann, Oort and Meijer, 2013). The task requires participants to actively shift their attention between an initial stimulus, while simultaneously processing others, in order to correctly detect different target sequences, corresponding to cognitive flexibility. This demonstrates a link between longer sleep duration and better cognitive flexibility performance in youth.

In all, a great deal of evidence directly links sleep duration and efficiency with all three EF subcomponents; working memory, inhibitory control and cognitive flexibility.

3.2 Sleep and Emotional Information Processing

Sleep has been shown to be associated with emotional information processing and regulation, key processes needed for the proper function of Affective ToM.

Sleep deprivation is associated with altered brain activation when viewing negative salient emotional stimuli (Yoo et al., 2007). Those who are sleep deprived experience a greater magnitude of amygdala activation when seeing aversive stimuli. This demonstrates that shortened sleep duration intensifies emotional reactivity, which challenges the ability to
successfully regulate ones’ own emotions. Also, compared to non-sleep deprived individuals, sleep deprived participants who viewed emotional stimuli on pictures showed reduced functional connectivity between the amygdala and medial prefrontal cortex, an area found to be involved in the top-down modulation of emotional processing and responses (Yoo et al., 2007).

Additionally, sleep deprivation elevates the activation of the ventral anterior cingulate cortex (Wu, Buchsbaum, and Bunney, 2001). Increased activation of the ventral anterior cingulate cortex is linked to detecting and regulating emotions in school aged children (Perlman and Pelphrey, 2011).

Shorter sleep duration and poor sleep quality has been associated with reduced emotional information processing abilities in both adults and youth (Berger et al., 2012; Deline, Glison, and Peigneux, 2014; Vriend et al., 2013). This includes an impaired ability to match emotions to faces (Soffer-Dudek et al., 2011), a ToM deficit (Cambell, 2012). A 2011 study (Soffer-Dudek et al., 2011) found that elevated night awakenings and decreased sleep efficiency predicted poor performance in identifying simple facial emotions (e.g., happy and sad) in school aged children.

Furthermore, neuroimaging studies have found longer sleep duration and “sleep credit” (sleeping more than the minimal duration needed to avoid impairment), are related to greater grey matter volume of the medial frontal and orbitofrontal cortex regions and also associated with higher emotional intelligence (Killgore, 2013; Weber et al., 2013). Emotional intelligence includes the ability to respond flexibly to changing emotional information and understanding others’ emotions (Killgore, 2013; Weber et al., 2013).

All of these emotional processing and regulating abilities disrupted by poor sleep duration and efficiency, are directly needed for successful affective ToM.

Overall, shorter sleep duration and lower sleep efficiency are associated with impaired
ability to regulate one’s own emotions and process emotional information, which are central to successfully understanding other people’s emotional mental states.

**4.0 The Present Study - Sleep and ToM: Are They Associated?**

A large body of evidence has shown that poor sleep is associated with impaired EF and with poor emotional information processing abilities. Both of these impairments correspond to ToM deficits. Neural networks disrupted by poor sleep also correspond to brain areas involved in the affective and cognitive ToM network.

Given EF is strongly entrenched in the development of ToM, and poor sleep impairs EF ability, we propose that poor sleep may be associated with poor cognitive ToM. Based on evidence demonstrating that poor sleep worsens the ability to process emotional information (such as emotions on faces), we propose that poor sleep will be associated with poor affective ToM.

The objective of this pilot study was to examine whether sleep is associated with affective and cognitive ToM in typically developing school aged children. Given the evidence linking short sleep duration and low sleep efficiency to poor EF and emotional processing impairments all of which are associated with poor ToM, we hypothesize the following:

1. **Shorter sleep duration is associated with poorer affective and cognitive ToM**
2. **Lower sleep efficiency is associated with poorer affective and cognitive ToM**
3. **Sleep moderates the association between EF and ToM, so that children with poor sleep will have poorer EF and poorer ToM and children with better sleep will have better EF and better ToM**
Methods

Participants

31 typically developing school children aged, between the ages of 8 to 11 years ($M = 9.69$ years $SD = 1.01$), participated in the study.

Participants were excluded if they: 1) had any parent reported medical and/or psychiatric disorder condition or medication which could interfere with children’s sleep; 2) performed two standard deviations below average on the verbal comprehension and perceptual reasoning index as measured by subtests on The Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003). 6 children did not meet the eligibility requirements during phone screening, and two children were excluded during the home assessment as they no longer met inclusion criteria. A total of 25 children were included in the final analysis.

Recruitment methods included flyers and online advertisements through local schools, day-cares, after school programs, psychologists, and other child services in the Montreal, Quebec area. This study was approved by the Douglas Mental Health University Institute ethics review board, and all children and parents signed consent forms during the screening process and once eligible for the study.

Measures

Demographics

**Health Information Form** was used to collect information from parents regarding any allergies and illnesses of their child, as well as the dosage and frequency of any medication that they may have taken. It also included a set of demographic questions.
about the child and family (i.e., household income, education level, ethnic background, marital status,

The Verbal Comprehension Index and the Perceptual Reasoning Index of The Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003). These indices were used to ensure all participants would be able to understand the tasks and materials presented to them. Participants who performed 2 standard deviations below the mean were excluded from the study during screening. The WISC-IV is an intelligence test designed for children ages 6 years to 16 years and 11 months.

The indices included in this study were:

Verbal Comprehension Index (VCI): The VCI assessed participant’s ability to listen to a question and draw upon learned information from their environment, this reflected the use of verbal skills to new situations. Three subtests of the VCI were administered: 1) the Vocabulary task that measured word knowledge and retrieval (reliability coefficient = .89); 2) the Similarities task used to measure verbal concepts and reasoning (reliability coefficient = .86) and; 3) the Comprehension task, that measured social knowledge and awareness (reliability coefficient = .81).

Perceptual Reasoning Index (PRI): The PRI measured participant’s ability to interpret and organize visual material, create solutions, and then test them. Three subtests of the PRI were administered: 1) the Block Design, that measured visual spatial reasoning and visual-constructional ability (reliability coefficient = .86); 2) the Matrix Reasoning task,
which measured non-verbal reasoning and concept formation (reliability coefficient = .89); 3) the Picture Concepts task was used to measure abstract and categorical reasoning (reliability coefficient = .82).

Sleep

Actigraphy. Nighttime sleep was monitored with actigraphy. Actigraphy allows for sleep to be measured in the child’s home environment, providing ecological validity. The device uses an accelerometer to record motor movement throughout the night, which is then used to estimate sleep-wake cycles. Actigraphy has been shown to be a reliable method for evaluating sleep in typically developing children (Bélanger et al., 2013; Meltzer et al., 2016). It has been validated against polysomnographic measures (Meltzer, Walsh, Traylor, & Westin, 2012).

In the present study wristwatch-like devices (AW-64 series and Actiwatch-2 Mini-Mitter) were used. Using the Phillips Actiware Sleep 6.0.0 software (Mini-Mitter), the total sum of activity counts was computed for each 1-min epoch. If the sum exceeded a threshold sensitivity value of the mean score during the active period/45, then the epoch was considered waking. Otherwise, the epoch was considered sleep. Reported bedtimes and wake times (provided by sleep logs) were used as the start and end times for the analyses and set by the researcher based on sleep log and the actigraphy data.

Both sleep duration and sleep efficiency were used for this study. Sleep duration is defined as the sum of epochs between sleep onset and sleep end that are scored as “sleep” according to the algorithm provided by the actiware sleep software. Sleep efficiency is defined as the percent of time in bed spent sleeping. These measures were averaged over five week nights, allowing to examine the children’s habitual sleep patterns.
Sleep logs. Sleep logs included information regarding children's bedtimes, waking times, and medication intake. They were completed by each participant with the assistance of a parent on a daily basis.

Executive Functioning

The Continuous Performance Test (CPT; Conners, 1994) is a standardized computerized assessment of sustained attention. Single letters are presented on a computer screen at 3 different rates: once per second, once every 2 s, or once every 4 s. Over the course of the test (~ 15 min), participants were asked to press a button in response to every signal except the target signal (the letter X).

This study used the commissions variable, an index of inhibitory control. Commissions refer to false positive errors (Soreni et al., 2009), which is the failure to stop a response to a stop signal trial (i.e., pressing when there is a letter “X”).

The Conners 3-Parent Short Form (Conners 3 P(S); (Conners 1997) is a 43 item questionnaire used to obtain parent’s observations about their child’s behaviour and includes an executive functions domain, primarily measuring working memory, cognitive flexibility (attention shifting) and planning. Parents responded to each item with either not true at all (never, seldom), just a little true (occasionally), pretty much true (often, quite a bit), or very much true (very often, very frequent). Internal consistency coefficients range from .85 -.94, with a good test-retest reliability of .85. The executive functions domain scale contained 5 items measuring, with a maximum raw score of 15. Raw scores were transformed into normalized T-scores. The
Theory of Mind

Affective ToM

*Reading of the Mind in the Eyes Test (RMET; Baron-Cohen et al., 2001).*

The *RMET*, was used to assess decoding complex emotional states and thoughts through facial recognition. 28 black and white pictures (15 cm x 6 cm) of eye regions were presented on a computer screen in randomized order, with four different emotions labeled to possibly describe what the displayed person might be thinking or feeling. Participants were instructed to look carefully at the pictures of eye regions presented and pick the emotional state (adjective), out of the four displayed on screen, that best described the person in the picture (*see Appendix A for an example*). Participants verbally selected the adjective, while a researcher pressed one of four keys on the keyboard, which corresponded to the spatial location of the selected adjective on the screen. Once the child picked an emotional state they moved on to the next picture, until they completed all 28. One test example was given at the beginning, to ensure participants understood the instructions. Every correct response was worth one point. A greater total score corresponded to better task performance.

Mixed Affective and Cognitive ToM

*Faux Pas Recognition Task (FPR; Baron-Cohen et al., 1999).* The FPR was used to evaluate the ability of participants to recognize a social ‘faux pas’, that can be described as a social situation in which a speaker says something without considering or understanding if it is something the listener wants to hear or know (*See Appendix B for an*
example). Understanding a social faux pas required the ability to use advanced cognitive and affective theory of mind. Participant’s needed to have a fundamental understanding that the speaker’s knowledge state may differ from that of the listener, in addition to having an appreciation for the emotional impact that may be caused.

The task consists of ten faux pas stories and ten control stories. Participants listened to an audio recording of each story, narrated by the researcher. Following each story an administrator asked a series of follow up questions in order to assess if the participant successfully identified that a faux pas had been committed. Four questions were asked after the faux pas story, the first question assessed if the child detected whether a faux pas was present (“In the story did someone say something that they should not have said?”). The second question ensured that the child identified the correct utterance as the faux pas (“What did they say that they should not have said?”). The third question ensured that the child understood the story and payed attention, so that a failure to identify a faux pas was not due to verbal comprehension problems or distraction (questions differed with each story). The fourth and last question determined if the child understood the faux pas was a consequence of the speaker’s false belief rather than an action with malicious intent (“Did they know/ remember that... “). A point was given for each correct response, with a possible high score of four for each faux pas story. Higher scores on the task corresponded with greater ToM performance, with the highest possible score being 40.

Confounding Variables
The Beck Anxiety Inventory For Youth (BAI-Y; Beck et al., 2005). The BAI-Y assess symptoms associated with anxiety in youth and can be used on children aged 7-18 years. The scale consist of 20 items and responses raged from 0 (Never) to 3 (Always). Higher scores correspond to greater anxiety symptomology. A total raw score was calculated by adding the scores for all 20 items. Raw scores were then transformed to standardized T scores using computed means and standard deviations for normative groups (by age and by gender). Based on normative data from a sample of 800 children, the BYI-II yields Chronbach’s Alpha coefficients ranging from .86 to .96 indicating high internal consistency, with a test-retest reliability ranging from .74 to .93. The BAI-Y was used to control for anxiety symptomology, as it has been associated with ToM deficits (e.g., Hezel & McNally, 2014).

The Beck Depression Inventory For Youth (BDI-Y; Beck et al., 2005) was used to identify symptoms of depression, including negative thoughts about self or life, and future; feelings of sadness; and physiological indications of depression in youth aged 7-18. The scale is consisted of 20 items and responses ranged from 0 (Never) to 3 (Always). Higher scores correspond to greater depression symptomology. A total raw score was calculated by adding the scores for all 20 items. Raw scores were transformed to standardized T scores using computed means and standard deviations for normative groups (by age and by gender). Based on normative data from a sample of 800 children, the BYI-II yields Chronbach’s Alpha coefficients ranging from .86 to .96 indicating high internal consistency, with test-retest reliability ranging from .74 to .93. The BDI-Y was used to control for depressive symptomology, as it has been associated with ToM deficits (e.g., Zobel et al., 2010).
Procedure (Figure 3)

Eligibility

Prior to study enrolment, eligibility was determined with an initial phone interview to screen for any medical and/or psychiatric disorder condition or medication. After passing the telephone screening and receiving informed consent from both the parent(s) and child to continue eligibility screening, a second screening was conducted in the homes of potential participants, lasting approximately 1.5 hours. Subtests of the Verbal Comprehension Index and Perceptual Reasoning Index on The Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003) were administered to potential participants to assess whether they would be able to understand tasks presented to them in the study.

Study

After initial screenings, parents of eligible participants received questionnaires including a demographic and health survey and sleep assessment battery. Participants were given an actiwatch and sleep log, along with written instructions that a researcher went over with both the parent and child. Parents helped their child document bedtimes and wake-times over 5 nights on the sleep log, while children wore an actiwatch for five nights to assess sleep efficiency and duration. Participants were further instructed to avoid products containing caffeine (e.g., chocolate or sodas) for the entire study, as it has been shown to disrupt natural sleep patterns and behaviour (Temple, 2009).

On the 6th day, after 5 nights of sleep recording, participants affective and cognitive ToM was measured using two tasks, the Reading the Mind in the Eyes test (Baron-Cohen et al., 2001) and the Faux Pas Recognition test (Baron-Cohen et al., 1999)
respectively. Participant’s inhibitory control was also assessed using The Continuous Performance Test (CPT; Conners, 1994). Children were asked to fill out The Beck Anxiety Inventory For Youth (BAI-Y; Beck et al., 2005) and The Beck Depression Inventory For Youth (BDI-Y; Beck et al., 2005), after they had completed the ToM and CPT tasks.

In total, this visit took approximately one hour to complete and was either done at the Attention Behaviour and Sleep Laboratory at the Douglas Mental Health University Institute or in a quiet room in the participant’s home. Prior to testing, parents and children were given secondary consent forms to complete.

Children were given a small toy and a ticket to the cinema for their participation. At the end of the study parents received a sleep report, which contained their child’s actigraphy data, along with sleep hygiene recommendations.

**Statistical Analysis**

*Power Analysis.* An a priori analysis was done on g power to determine the number of participants needed to reach 80% power, with a moderate effect size (Cohen’s $d = .60$). Using a multiple regression model with 2 predictor variables, a total sample size of 32 participants was recommended for our pilot study.

*Descriptive Statistics.* Means and standard deviations were calculated for recorded demographic and variable characteristics using the statistical software package SPSS, Version 23.0. Scores of different batteries were calculated using the manual guides of each specific battery.
**Covariates.** Potential confounding variables that were significantly associated with either ToM outcome (RMET or FPR), were added to the main regression analysis model. Age, depressive and anxiety symptomology were analyzed using Pearson correlations, while an independent samples t test was performed to determine if there were any gender differences in ToM performance.

**Factor analysis.** Principal-component analysis with a varimax rotation was preformed using the CPT commissions variable and Conner’s EF subscale scores, to determine if one EF variable containing subcomponents frequently associated to ToM could be amalgamated.

**Regression Analysis.** Parallel multiple hierarchical regression analyses were conducted to determine whether sleep duration or efficiency was associated with ToM performance, and whether sleep duration or efficiency moderated the relationship between EF and ToM performance.

Affective ToM and mixed affective and cognitive ToM performance (measured by the Reading the eyes in the Mind Test and the Faux Pas Task, respectively) served as the ToM dependent variables. In accordance with recommendations from Aiken and West (1991), separate regression analyses were conducted using the following order of variables entered: **Step 1** sleep duration and sleep efficiency were separately added in the first model for each regression model. This main effect model determined if sleep duration or sleep efficiency were associated with performance on both ToM tasks, measuring affective and cognitive ToM. Hence,
one regression model looked at the association between sleep duration and affective ToM ability in the first step, while another separate parallel regression looked at the association between sleep efficiency and affective ToM ability. Two other equivalent regression models were analyzed for the other DV, mixed affective and cognitive ToM. **Step 2)** The executive functioning variable was added to all parallel regressions in the second regression model. This main effect model was used to determine if executive functioning was associated with ToM task performance. **Step 3)** Interaction terms between sleep and executive functioning (e.g., sleep duration X executive functioning and sleep efficiency X executive functioning) was used for each parallel regression to determine if sleep duration or efficiency moderated the relationship between executive functioning and performance on ToM measures.

All product terms used in the interactions above were centralized to avoid issues of multicollinearity. Each regression model was controlled for any identified covariates significantly associated with a ToM measure (i.e., age, anxiety or depression).

SPSS version 23.0 was used for all statistical tests and a p value of <0.05 was considered to indicate statistical significance.

**Results**

*Demographics*

Demographic and descriptive characteristics of the study participants are presented in Table 1.

*Covariates*
Age, depressive and anxiety symptomology were not associated with any ToM outcomes, nor were any gender differences found in ToM performance, in either task.

**Factor Analysis**

Principal-component analysis using a varimax rotation produced a one-factor solution from the CPT commissions variable and Conner’s EF subscale scores, measuring inhibition, working memory and task shifting, respectively. The factor accounted for 52.64% of the variance (the eigenvalue was 1.05). This factor was termed executive functioning (EF).

**Regression Analyses**

All relevant assumptions for hierarchical multiple regressions were tested and satisfied. Collinearity statistics, examined with Tolerance and Variance Inflation Factor (VIF) results, were within the accepted limits for all models (Coakes, 2005).

*Associations between affective ToM and mixed affective and cognitive ToM with sleep duration and EF*

No significant associations were found between affective ToM and mixed affective and cognitive ToM ability and sleep duration. No significant interaction terms were found. Regression results are reported in Table 2.1.

*Associations between affective ToM and mixed affective and cognitive ToM with sleep efficiency and EF*
No significant associations were found between affective ToM and mixed affective and cognitive ToM ability and sleep efficiency. No significant interaction terms were found. Regression results are reported in Table 2.1.

**Discussion**

No significant associations were found between children’s sleep efficiency or duration with their performance on either affective or cognitive ToM tasks. Furthermore, our findings revealed EF was not associated to children’s performance on either ToM task, while neither sleep efficiency or sleep duration moderated a relationship between EF and ToM. These results are not in line with previous literature in adolescents that have found lower sleep efficiency is correlated to poor performance on tasks related to affective ToM, like emotion facial recognition (Soffer et al., 2011). Additionally, these results do not mirror findings demonstrating that impaired cognitive ToM, such as inability to detect non-literal language, is associated with shorter sleep duration in adults (Deliens, 2015).

The strengths of the study are: 1) It is the first to propose and examine the relationship between sleep and ToM in school age children; 2) An objective sleep measure was used to collect information in an ecologically valid manner using actigraphy in youth’s homes; and, 3) The use of an aggregate approach to assess EF, capturing an underlying commonality from various measures of subcomponents, including: inhibitory control, cognitive flexibility and working memory. By collapsing two EF measures (Conner’s Continuous Performance Test and the Conners Parent Short Form) from two different respondents (children and parents), it was possible to derive an EF score that captured a wide array of the participants EF abilities.
This study sought to examine the relationship between sleep and ToM in school aged children. Based on evidence that poor sleep impairs emotional information processing and executive functioning abilities, we hypothesized that shorter sleep duration and lower sleep efficiency would be associated with poorer ToM. Our current findings do not support this hypothesis, as shorter sleep duration and lower sleep efficiency were not associated with poorer performance on the Reading the Eyes in the Mind Task and the Faux Pas Recognition Task, measuring affective and cognitive ToM. It was further hypothesized that sleep would moderate the association between EF and ToM, so that children with poor sleep would have poorer EF and poorer ToM and children with better sleep would have better EF and better ToM. However, our results revealed that participant’s sleep duration and sleep efficiency was not associated with EF performance on either the Continuous Performance Task or the Conners Parent Short Form. No significant interaction was found between sleep duration or efficiency with EF and ToM, hence, our initial hypothesis was not supported. Although, there were many strengths that allowed us to explore these hypotheses, some limitations made it difficult to fully examine this relationship.

**Limitations**

*Small variability among participants’ sleep duration.* Although small variations between children’s sleep duration was seen, the majority of participants were “good sleepers.” Participant’s mean sleep duration was 541.5 minutes (9.03 hours), which fits the recommended sleep duration for school-age children according to the National Sleep Foundation (NSF; Hishkowitz, 2015), American Academy of Sleep Medicine (AASM; Paruthi et al., 2016) and the Canadian 24-Hour Movement guidelines (Tremblay et al., 2016). Such small variability among
participants’ sleep duration may not be sufficient to detect associations that might occur with ToM performance, if such exists.

*Sample* homogeneity. Children’s race and SES have been shown to be associated with sleep duration in youth (Buckhalt, El-Sheikh, and Keller, 2007; Hale and Do, 2007; Spilsbury et al., 2004). However, our participant sample was homogenous, children were predominately Caucasian and came from educated and high socio-economic status (SES) families, which may explain the lack of variability in sleep duration and efficiency.

*Sample Size.* Although the sample size was adequate for a pilot study, there were not enough participants to observe larger variability in children’s sleep duration and efficiency. Future studies should consider increasing the sample size to increase the likelihood of sleep variability within the sample.

*Timing of Sleep Measurement.* To accommodate for busy parent schedules often times children’s sleep had to be assessed over the weekend or during school breaks. This may not accurately represent an individual’s regular weekday sleep pattern, as previous research has shown youth tend to compensate for sleep loss during the school week, by sleeping more during weekends (Crowley et al., 2007; Kim et al., 2012; Szymczak et al., 1993). Therefore, it would be ideal to solely collect sleep data from youth during nights that precede a school day.

*Ceiling Effect in Performance on the ToM Task.* 72% of the participants scored 80% or higher on the Faux Pas Recognition task. This strong performance on the task may indicate a low difficulty level for our sample, which may not fully capture their use of affective and cognitive
ToM. This ceiling effect, might indicate the FPR measure was too easy for participants. This is problematic because it results in low test score variability. In order to address this problem, a diverse range of tasks assessing affective and cognitive ToM should be used in the future to limit issues like difficulty level, but also to capture a fuller understanding of ToM capabilities through multiple ways that engage youth. Adding ToM tasks that also use different modalities (e.g., audio, videos) may also be helpful in monitoring if task presentation effects children’s performance. For instance, the Happe Strange Story Task (Happe, 2004) is another sophisticated ToM task that could be used to assess cognitive ToM. This situational story task can be presented in video or audio format, and assess youth’s ability to detect nonfigurative language, like sarcasm and metaphors, and also deception.

**Conclusion**

The preliminary results of our pilot study reveal no significant association between sleep duration or sleep efficiency with affective and cognitive ToM. Neither sleep duration nor efficiency was found to moderate the relationship between EF and ToM. Future research using a larger participant sample size with greater sleep variability may clarify the relationship between sleep and ToM.
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Table 1.

Sample characteristics of participants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percent (%)</th>
<th>$M$</th>
<th>$SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (F/M)</td>
<td>48/52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>9.69</td>
<td>1.01</td>
<td></td>
</tr>
<tr>
<td>Pubertal development</td>
<td>1.59</td>
<td>0.42</td>
<td></td>
</tr>
<tr>
<td>WISC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal Comprehension</td>
<td>128.31</td>
<td>11.02</td>
<td></td>
</tr>
<tr>
<td>Perceptual Reasoning</td>
<td>115.50</td>
<td>12.13</td>
<td></td>
</tr>
<tr>
<td>BAI (T score)</td>
<td>47.21</td>
<td>7.93</td>
<td></td>
</tr>
<tr>
<td>BDI (T score)</td>
<td>47.75</td>
<td>8.73</td>
<td></td>
</tr>
<tr>
<td>Ethnic background(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mutli-ethnic</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Family household

income

(Per year %)

- $25,000 - $45,000: 8.7
- $45,000 - $65,000: 4.3
- $65,000 - $95,000: 0
- + $95,000: 87

Highest level of educational

(mother/father %)

- College/CGEP (nf): 8.7/8.7
- College/CGEP (f): 8.7/4.3
- Undergraduate: 4.3/8.7
- Undergraduate: 17.4/26.1
- Graduate: 60.9/52.2

Marital status (%)

- Married: 87
- Divorce: 8.7
- Single: 4.3
**Sleep Measures**

Sleep duration  
541.51(mins)  37.32(mins)

Sleep efficiency  
81.51(%)  3.50(%)

**Theory of Mind**

RMET  
18.44  2.95

FPR  
8.16  1.37

**Executive Function**

CPT commissions  
52.91  8.15

Conners 3P(S) EF  
54.28  11.93

---

**Note.** WISC-IV = Wechsler Intelligence Scale for Children, BAI = Beck’s Anxiety Inventory for Youth, BDI = Beck’s Depression Inventory for Youth, RMET = Reading the Mind in the Eyes Test, FPR = Faux Pas Recognition Task, CPT commissions = Continuous Performance Task commission scores, Conners 3P(S) EF = The Conners 3-Parent Short Form, executive functioning subscales
Table 2.1

*Associations between affective ToM and mixed affective and cognitive ToM with sleep duration (SD) and Executive Functions (EF).*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Affective ToM</th>
<th></th>
<th>Mixed affective and cognitive ToM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE B</td>
<td>β</td>
<td>B</td>
</tr>
<tr>
<td><strong>Main effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Model 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>-.01</td>
<td>.02</td>
<td>-.10</td>
<td>.01</td>
</tr>
<tr>
<td>Total R^2 (adjusted)</td>
<td>-.04</td>
<td></td>
<td>.10</td>
<td></td>
</tr>
<tr>
<td><strong>Main effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Model 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>-.00</td>
<td>.02</td>
<td>-.04</td>
<td>.01</td>
</tr>
<tr>
<td>EF</td>
<td>.36</td>
<td>.78</td>
<td>.12</td>
<td>-.05</td>
</tr>
<tr>
<td>Total R^2 (adjusted)</td>
<td>-.08</td>
<td></td>
<td>-.04</td>
<td></td>
</tr>
<tr>
<td><strong>Interaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Model 3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>-.003</td>
<td>.02</td>
<td>-.04</td>
<td>.01</td>
</tr>
<tr>
<td>EF</td>
<td>-1.14</td>
<td>8.87</td>
<td>-.37</td>
<td>-.81</td>
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<tr>
<td>SD X EF</td>
<td>.00</td>
<td>.02</td>
<td>49</td>
<td>.00</td>
</tr>
<tr>
<td>Total R^2 (adjusted)</td>
<td>-.13</td>
<td></td>
<td>-.09</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* B and β refer to the unstandardized and standardized partial regression coefficients, respectively, and SE B refers to the standard error of the unstandardized coefficient. Total R^2 (adjusted) values refer to the variation accounted for by the model. Mental state decoding = Reading the Mind in the Eyes Test, SD = Sleep duration, EF = Executive Functioning Sub Scale. *p ≤ .05
Table 2.2

Associations between mixed affective and cognitive understanding with sleep efficiency (SE) and Executive Functions (EF).

<table>
<thead>
<tr>
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<th>Mixed affective and cognitive ToM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$B$</td>
<td>$SE_B$</td>
</tr>
<tr>
<td><strong>Main effects (Model 1)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>.01</td>
<td>.18</td>
</tr>
<tr>
<td>Total R$^2$ (adjusted)</td>
<td>.10</td>
<td></td>
</tr>
<tr>
<td><strong>Main effects (Model 2)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>.00</td>
<td>.19</td>
</tr>
<tr>
<td>EF</td>
<td>.41</td>
<td>.68</td>
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<tr>
<td>Total R$^2$ (adjusted)</td>
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<td></td>
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<tr>
<td><strong>Interaction (Model 3)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>.00</td>
<td>.19</td>
</tr>
<tr>
<td>EF</td>
<td>-5.5</td>
<td>18.5</td>
</tr>
<tr>
<td>SE X EF</td>
<td>.07</td>
<td>.22</td>
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<td>Total R$^2$ (adjusted)</td>
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</table>

*Note.* $B$ and $\beta$ refer to the unstandardized and standardized partial regression coefficients, respectively, and $SE_B$ refers to the standard error of the unstandardized coefficient. Total R$^2$ (adjusted) values refer to the variation accounted for by the model. Mental state decoding = Reading the Mind in the Eyes Test, SE = Sleep efficiency, EF = Executive Functioning Sub Scale. *$p \leq .05$*
Figure 1. Flowchart demonstrating links between ToM and executive functions (EF). Theory of mind is split into a) Cognitive ToM: the ability to understand and make inferences about other’s beliefs and intentions and b) Affective ToM: the ability to understand and make inference about other’s emotions and feelings. Presented are the links found in literature (e.g., Devine and Hughes, 2014, Apperly, Warren, Andrews, Grant & Todd, 2011, Austin, Groppe, and Elsner, 2014) between affective and cognitive ToM in youth, with three EF subtypes: 1) cognitive flexibility, 2) working memory, 3) inhibitory control. In addition to associations with EF, affective ToM is also associated with emotional information processing and regulation, needed to understand various feelings and emotions of others’ and themselves.
Figure 2. Conceptual framework demonstrating links between sleep and executive functions (EF). The present chart demonstrates the links found in the literature between two sleep variables: a) **sleep efficiency**: the percent of time in bed spent sleeping and b) **sleep duration**: the amount of time spent in bed sleeping, and EF subtypes. Sleep duration is associated with cognitive flexibility (Dewald-Kaufmann, Oort and Meijer, 2013), working memory (Gruber et al., 2012; Sadeh et al., 2003; Vriend et al., 2013), and inhibitory control (Chuah et al., 2006; Drummond, Paulus, and Tapert et al., 2006; Gruber et al., 2011; Sadeh et al., 2003). Sleep efficiency is associated with working memory (Steenari et al., 2003) and inhibitory control (Sadeh, Gruber, and Raviv, 2002). Both sleep duration and efficiency have been shown to be associated with emotional information processing and regulation (e.g., Deline, Glison, and Peigneux, 2014; Soffer-Dudek et al., 2011; Wu, Buchsbaum, and Bunney, 2001; Yoo et al., 2007).
Figure 3. Study procedure flowchart

Notes. WISC-IV = The Wechsler Intelligence Scale for Children-Fourth Edition, VCI = Verbal Comprehension Index, PCI = Perceptual Comprehension Index, PDS = Pubertal Development Score, RMET= Reading the eyes in the mind test, FPR = Faux Pas Recognition task, CPT= Continuous Performance Task, BDI= Beck Depression Inventory, BAI= Beck Anxiety Inventory.
Appendices

Appendix A

Reading the Eyes in the Mind Task (Example)

The Reading the Eyes in the mind task (RMET) measures affective ToM. 28 black and white pictures of emotional facial stimuli were shown to participants on a computer screen. Youth were required to pick an emotional state word out of the four on screen (e.g., Jealous, Scared, Relaxed or Hate), that best described how a person was thinking or feeling in photographs presented to them of the eye regions of human faces.
Appendix B

Faux Pas Recognition Task (Example)

**Story:** James bought Richard a toy airplane for his birthday. A few months later, they were playing with it, and James accidentally dropped it. “Don’t worry” said Richard, “I never liked it anyway. Someone gave it to me for my birthday”.

**Faux Pas Detection Question:** In the story did someone say something that they should not have said?

**Identification Question:** What did they say that they should not have said?”

**Comprehension Question:** What did James give Richard for his birthday?

**False Belief Question:** Did Richard remember James had given him the toy airplane for his birthday?