Eveningness and cognition/behavior in school-aged children: What is the role of sleep quantity and sleep quality?

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Preface

While some people are alert in the morning and wake up early, others prefer to go to bed late and have their peak of alertness in the evening. This phenomenon is described as chronotype. Recent research indicates that evening preference is associated with worse cognitive and behavioral daytime functioning in adults and children, which for instance leads to low academic achievement. Little is known so far about the possible pathways in these associations. The current study aimed to broadly explore these pathways in school-aged children in order to make a start in unraveling possible mechanisms. A better understanding could lead to (clinical) interventions and prevent children from more problems.

This study was conducted under supervision of Dr. K.B. van der Heijden at the University of Leiden, Department of Clinical and Adolescent Studies, and has resulted in my master thesis of the research master 'Developmental Psychopathology in Education and Child Studies'. Of course, I was not able to move along this project without help and support. I would like to thank my supervisor Kristiaan for his coaching, wise words and inspiration. Working together was not only very informative, but also fun! Of course, I would also like to thank the participating children, their parents, and the schools for their cooperation and the master students responsible for the data collection. Finally, I would like to thank my parents and Niels for their support and motivating words, as well as my fellow (research master) students for the shared coffee-breaks and helpful advices.

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Abstract

This study explored the relation between chronotype and cognitive and behavioral problems in 333 school-aged children (mean age 9.97 years, 55% girls), with an important focus on a potential mediating role of sleep duration and sleep quality. Participants completed short-form WISC-III^{NL} and several tasks on the Amsterdam Neuropsychological Tasks (ANT), which assesses important domains of attention. Their parents filled out a sleep log and several questionnaires regarding chronotype (CCTQ), sleep habits (CSHQ), and behavioral problems (CBCL). Results showed that indeed eveningness was associated with behavioral problems. No direct associations with cognitive functioning were found. Sleep duration was not associated with cognitive-behavioral functioning. Sleep quality, specifically feeling rested in the morning during weekdays, was associated with cognitive and behavioral functioning. Several mediating relations were identified. The findings highlight that sleep quality partially mediates the relation between chronotype and cognitive-behavioral problems. Evening types show behavioral problems when they do not feel rested in the morning. These findings have significant clinical implications.

Keywords: eveningness; sleep; attention; behavior; children

Introduction

While some people wake up early and are alert in the morning, others prefer to go to bed late and are at their peak in the evening. These different rhythms are described as ‘chronotype’. Because of everyday social rhythms such as school and work, people are not free to choose at what time they wake up during weekdays. Consequently, evening-type persons have less sleep, since they go to sleep later in the evening and therefore are at risk of developing sleep debt during weekdays. Recent research among adults as well as children indicates that especially these evening-type persons are at risk for developing behavioral and emotional problems and experience increased daytime sleepiness, which in turn is associated with suppressed cognitive functioning (e.g., Gianotti, Cortesi, Sebastiani, & Ottaviano, 2002; Gau et al., 2007; Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009; Lange & Randler, 2011). These problems place a huge social and financial burden on society and are therefore important to tackle at an early stage.

To date it is still unknown what exact mechanisms are at the root of these aspects, from chronotype (time-of-day preference) to cognitive and behavioral problems. Possibly, less sleep and a worse sleep quality, partly reflected in a stronger variability in sleep duration between weekdays and weekends in evening persons and increased sleepiness, may account for suppressed daytime cognitive capacities and reduced alertness, and negatively influence behavior. This study seeks to explore the relation between eveningness, cognition, and behavior in school-aged children and assess several hypotheses about potential underlying mechanisms. More insight into these mechanisms will make it possible to address at problems with cognition and behavior as a consequence of sleep-wake pattern at an early stage and can be especially valuable for clinicians, schools, and parents.

Individuals have an approximately 24-hour rhythm (circadian rhythm) which is modulated by the biological clock. About 50% of the circadian preference is genetically determined (Hur, Bouchard, & Lykken, 1998; Vink, Groot, Kerkhof, & Boomsma, 2001). This makes a person’s chronotype reasonably stable from childhood to adulthood, although during adolescence there is a shift towards more eveningness, which subsequently declines again (Carrier, Monk, Buysse, & Kupfer, 1997; Roenneberg et al., 2007). The different circadian preferences are called chronotype; individual differences regarding the time of day at which people prefer to be active. Some persons wake up early and are alert in the morning. They are described as morning types (larks). Others prefer to go to bed late and have their peak in the evening; they may be named evening types (owls). However, many people are not at these extreme ends of the continuum and are described as neither type (Natale & Cicogna, 2002). Evening persons are at risk of sleep debt since they go to sleep later in the evening and still have to wake up early in the morning to meet social schedules. They compensate for their weekday sleep loss in the weekend, when they sleep significantly longer. This makes their sleep-wake rhythm very variable compared to the morning types, who do not extend their sleep duration as much during weekends (Taillard, Philip, & Bioulac, 1999).

Thus, time-of-day preference, or morningness/eveningness, is influenced by processes regulated by the biological clock and can be measured by means of markers of the biological clock. For example, body temperature, melatonin secretion, and cortisol levels during the day differ for morning types and evening types (Kerkhof & Van Dongen, 1996; Hofstra & De Weerd, 2008; Lack, Bailey, Lovato, & Wright, 2009). In children, these markers have been studied less. However, there are other ways to assess a person’s chronotype. Questionnaires and sleep diaries which give information about wake/sleep cycles and rest/activity can be useful. The best known and most widely used adult questionnaires regarding this topic are the morningness/eveningness questionnaire (MEQ; Horne & Ostberg, 1976), and the Munich Chronotype Questionnaire (MCTQ; Roenneberg, Wirz-Justice, & Merrow 2003). For children, fewer questionnaires are available. Carskadon (1993) developed the Morningness/Eveningness Scale for Children (MESC; Carskadon, 1993) by adapting adult questionnaires. Werner, LeBourgois, Geiger, & Jenni (2009) recently constructed the Children’s ChronoType Questionnaire (CCTQ). This instrument consists of multiple parent-report measures of chronotype: midpoint sleep on free days, a morningness-eveningness score, and a five-point chronotype score. The questionnaire is based on the MCTQ and the MESC. This is the first reliable and valid parent-report questionnaire to assess chronotype in children aged 4 to 11 years Werner et al., 2009).

Recently, chronotype has become a topic of interest in studies investigating sleep in relation to behavioral problems and school performance. Eveningness has been associated with a wide variety of behavioral and emotional problems. Gau et al. (2007) report more behavioral/emotional problems for adolescents with evening preference. These participants had higher scores on all scales of the CBCL and higher rates of substance abuse. Lange and Randler (2011) found similar results using the Strengths and Difficulties Questionnaire (SDQ). Another study comparing morning and evening types also revealed more behavioral problems for the latter group, and additionally found that evening-type adolescents are four times more likely than morning-types to display behavioral problems in the borderline/clinical range (Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2007). Adolescents with eveningness preference more often report poor school achievement and a tendency to fall asleep at school than their morning-type peers (Giannotti et al., 2002). Randler and Frech (2009) also found a highly significant negative correlation between average grades and chronotype, favoring morningness. Students with later bedtimes (i.e., evening types), less sleep, and variable sleep-wake rhythms perform worse at school than peers with an earlier bedtime at school (Wolfson & Carskadon, 1998; Wolfson & Carskadon, 2003).

How these relations can be explained has so far remained unknown. Several explanations are possible, which will be discussed here. Sleep property can be expressed along two dimensions: by sleep quantity and sleep quality. Sleep problems related to these dimensions are thought to lead to sleepiness (Carskadon, Harvey, & Dement, 1981; Fallone, Acebo, Arnedt, Seifer, & Carskadon, 2001; Fallone, Owens, & Deane, 2002), and sleepiness is more often reported by evening types (Russo, Bruni, Lucidi, Ferri, & Violani, 2007). Adults with increased sleepiness perform worse on cognitive performance tasks, with a more profound effect on the more complex tasks and those tasks dependent on attention and vigilance (Boonstra, Stins, Daffertshofer, & Beek,, 2007; Lim & Dinges, 2010). For children, similar results have been found (Randazzo, Muehlbach, Schweitzer, & Walsh, 1998; Sadeh, Gruber, & Raviv, 2002; Sadeh, Gruber, & Raviv, 2003; Curcio, Ferrara, & De Gennaro, 2006; Kopasz et al., 2010). Moreover, behavioral functioning has also been found to be related to sleepiness (Fallone et al., 2002).

Sleep quantity

The first possible explanation of the relation between eveningness and behavioral problems can be found in sleep duration. Evening types go to sleep later in the evening and still have to wake up at the same time as morning types, so that during weekdays they have less sleep and experience more sleep loss (Giannotti et al., 2002). Recent research has indicated that it is especially the prefrontal cortex (PFC) which is sensitive to sleep and sleep deprivation (Dahl, 1996a; Muzur, Pace-Scott, & Hobson, 2002). The PFC is mainly involved in executive functioning, which is an overarching concept for all systems that control and regulate other cognitive processes, including such skills as sustained attention, working memory, and problem solving. Insufficient sleep might lead to impaired executive functioning of the PFC, and have detrimental consequences for daily human performance (Pilcher & Huffcutt, 1996; Durmer & Dinges, 2005; Boonstra et al., 2007). More complex tasks are thought to entail higher levels of cognitive functioning, and require higher executive functioning. In a longitudinal study, sleep problems in children and adolescents from ages 4 to 16 were found to be significantly associated with executive control in late adolescence. When sleep problems decreased over time, participants performed better on tasks requiring executive functioning at age 17 (Friedman, Corley, Hewitt, & Wright, 2009). This highlights the possible reversibility of consequences. Although it is assumed that cognitive functioning after sleep loss is suppressed and that the higher-order cognitive domains are most impaired, there is no consensus on exactly which domains are affected. Results are sometimes inconclusive and even contradictory. Astill, Van der Heijden, Van IJzendoorn, and Van Someren (2011) conducted a review on studies assessing sleep and cognitive and behavioral functioning, and found a positive relation between these variables. It was especially declarative memory, general cognitive functioning, and school performance which appeared to be related to sleep duration. However, in this meta-analysis no association was found between sleep on the one hand, and attention and executive functioning on the other. Since the meta-analysis presented a diffuse picture across the different areas of interest, it is important to be aware of individual studies as well. Regarding general cognitive functioning, Gruber et al. (2010) found that longer sleep duration was associated with better performance on an IQ-test. Geiger, Achermann, and Jenni (2010) found a negative correlation between sleep duration and IQ score, in which chronotype was not of influence either. In contrast, Mayes, Calhoun, Bixler, and Vgontzas (2008) found no significant correlations between sleep and IQ scores in children in the same age range. This stresses the inconclusiveness of many results found on this topic. Other cognitive domains have been investigated in relation to sleep duration as well.

A reduction of sleep duration affects performance on several cognitive tasks, including visuospatial abilities, verbal creativity, abstract thinking, and memory (Randazzo, Muehlback, Schweitzer, & Walsh, 1998; Touchette et al., 2007; Paavonen et al., 2010). Steenari et al. (2003) found that sleep duration was associated only with performance on the highest load levels of the n-back task, i.e., tasks for which working memory is required most. Nevertheless, Sadeh et al. (2002) found no associations between sleep duration and neurobehavioral functioning. Differences were also found for children who restricted their sleep compared to those of whom sleep was extended, in particular regarding simple reaction time, working memory, and a sustained attention task (Sadeh et al., 2003). In a study by Geiger et al. (2010) attentional measures did not correlate with sleep variables, but working memory was found to be negatively correlated with sleep duration.

Sleep duration is also associated with behavioral problems. Dahl (1996a, 1996b) has already suggested that insufficient sleep could lead to problems in the regulation of attention and affect. In a sample consisting of young children (age 5-6), sleep duration and behavioral problems as measured by the Child Behavioral Checklist (CBCL) were negatively correlated (Paavonen, Porkka-Heiskanen, & Lahikainen, 2009). Touchette et al. (2007; 2009) also found an inversed correlation between sleep duration and hyperactivity-impulsivity. What was reported in these studies was especially sleepiness and inattention (cf. also Fallone et al., 2001). Gruber et al. (2010), however, did not find a relation between sleep duration and behavioral measures. Sleep reduction was also found to affect school performance in children aged 9 to 13 years (Meijer, Reitz, Dekovic, Van den Wittenboer, & Stoel, 2010). Contradictory results have been reported as well. For example, no relationship was found between sleep duration and grades in adolescents (Eliasson, Eliasson, King, Gould, & Eliasson, 2002).

Sleep quality

Sleep quality is a broad concept, which can be defined in multiple ways. It includes amongst others sleep efficiency, an index of sleep duration versus time in bed, and variability in the timing of sleep. Steenari et al. (2003) investigated the relations between sleep quality and performance on working memory tasks in 6-13 year-old children. Lower sleep efficiency and longer sleep latency (measures of sleep quality) were associated with more incorrect responses in working memory tasks at all levels of the n-back task. A broader perspective was taken by Sadeh et al. (2002). This association study monitored sleep for five nights using actigraphy. Significant correlations were found between quality of sleep and neurobehavioral functioning. Tasks requiring working memory and sustained attention proved most impaired, as did the more complex tasks. Time of day was found to be of influence on several outcome measures. Poor sleepers, i.e., those having fragmented sleep, have higher ratings of behavioral problems on several CBCL scales than good sleepers (Sadeh et al., 2002).

As said, variability in sleep timing is another indicator of sleep quality. The stability/variability of people’s sleep patterns is associated with chronotype. During weekdays, evening-type persons develop sleep debt as a consequence of their shorter nights. They compensate for this during weekends, in which they extend their sleep significantly (Taillard et al., 1999). Morning types have less variability in their sleep-wake rhythm over weekdays and weekends. Greater variability in bedtime and time of getting up, as well as several other indicators of social rhythm are associated with more disturbed sleep in adolescents (Carney, Edinger, Meyer, Lindman, & Istre, 2006). A greater regularity is associated with better subjective reported sleep. In children, night-to-night variability has been rarely studied. In a clinical sample more variability in sleep-wake variables has been found than in typical developing children (Anders, Iosif, Schwichtenberg, Tang, & Goodlin-Jones, 2011). Crowley and Carskadon (2010) found that adolescents sleeping 1.5 hour longer on weekend nights (Friday and Saturday) produce a phase delay of the biological clock, as indicated by dim light melatonin onset (DLMO), a phase marker of the biological clock rhythm. As a consequence, sleep phase has to be re-entrained (shifted back) during the first few days in the new week (school days) and might impact daytime functioning. During the first school nights, the onset of sleep pressure comes later in the evening, which shortens the total sleep duration. As discussed previously, this can have detrimental effects on cognitive and behavioral functioning. Other studies did examine the consequences of shifting the sleep-wake rhythm during the weekend. Yang and Spielman (2001) compared a week of normal sleep with a week in which the sleep schedule on Friday and Saterday nights was delayed by two hours. Participants had more difficulties falling asleep on Sunday night, and lower cognitive performance (word recall) and lower mood ratings were found on Monday morning. A comparable research design was used by Taylor, Wright, and Lack (2008), whose results indicate a significant delay in salivary DLMO and increased sleep onset latency, as well as greater daytime fatigue and sleepiness on the first few weekdays. O'Brien and Mindell (2005) found an association between the length of weekend delay on the one hand, and both self-reported risk-taking behavior and academic performance on the other. A study with preschool children revealed that the children's irregular bedtimes were associated with more aggressiveness and attention problems compared to children keeping/with regular bedtimes (Komada et al., 2011).

Some studies found a relation only for sleep efficiency and cognitive performance and behavioral problems, not for sleep duration. This may be explained by individual differences in the amount of sleep needed (Anderson et al., 2009). When an individual does not receive the right amount of sleep, whether this is six or ten hours, the consequence is sleepiness, which indirectly influences cognitive and behavioral functioning.

Attention and working memory

Attention is one of the most important functions with respect to learning, cognitive functioning, and information processing (Posner & Peterson, 1990; de Sonneville, 2005) Attention is not a one-dimensional construct but consists of several components. One of the most widely used models concerning attention is that proposed by Posner and Peterson (1990), which identifies three subcomponents of attention: orienting, alerting, and executive attention. The orienting network is used for the selection of specific information and can be described as a form of focused attention. The alerting network has the function to increase and sustain arousal and vigilance. Lastly, the executive network is involved in higher-order cognitive functions such as planning, inhibition, and error detection. For this last network working memory is of great importance (Redick & Engle, 2006). Matchock and Mordkoff (2009) investigated the effect of time-of-day and chronotype on tasks related to the three different networks. They did not find significant chronotype differences regarding the efficiency of the orienting network and executive control. Regarding the alerting network differences were found between morning types and evening types, with increased alertness of the morning types in the afternoon. The lack of results might be a consequence of the sample distribution, which included very few morning types. Working memory is facilitated by sleep (Kopasz et al., 2010), and relates to sleep efficiency and sleep duration (Steenari et al., 2003).

To summarize, as a consequence of shorter sleep duration and impaired sleep quality higher-order cognitive functioning as well as behavioral functioning and school performance seem to be impaired in children. Most studies indicate cognitive impairments in working memory and in sustained attention, and behavioral inattention. However, results are not consistent and sometimes even contradictory. Some studies included children with chronic sleep fragmentation, and other children only experienced one night of restricted sleep. Sleep measures also differ within studies, with some focusing on sleep quality and others on sleep duration. Several cognitive domains which are affected by sleep loss are important for school achievement: working memory (Andersson, 2008), general intelligence (Naglieri & Bornstein, 2003), and attention (Barriga et al., 2002; Steinmayr, Ziegler, & Träuble, 2010). As a consequence of cognitive and behavioral problems, school functioning and performance seems to be impaired. Several studies found a relation between sleep duration, chronotype, and academic achievement. In their review, Dewald, Meijer, Oort, Kerkhof, and Bögels (2010), found that sleep duration, as well as sleep quality and sleepiness, are associated with school performance in children.

This study

To prevent excessive chronotype-related problems for children regarding academic functioning, insights into the underlying mechanisms are important. Sleep loss seems to affect especially attention and working memory. Hence, this study explores the relations between chronotype (eveningness), sleep, cognitive functioning, and behavioral problems. The main research question is which underlying mechanisms, defined by sleep quantity and sleep quality, can be identified in the relation between eveningness on the one hand and cognitive and behavioral problems on the other. These relations are shown in the following model (Figure 1):

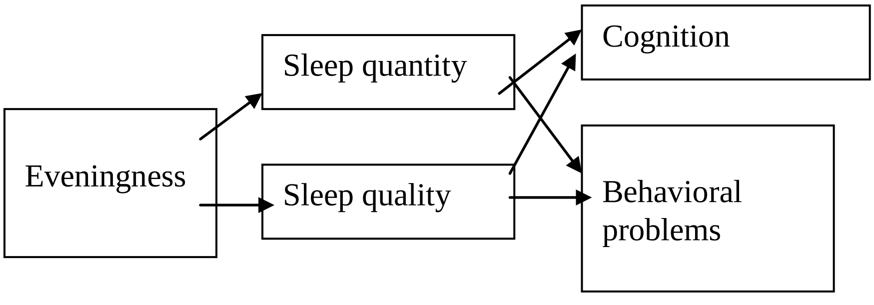

Figure 1. Relations explored in this study

This study is based on the following three hypotheses. (1) Eveningness is associated with behavioral en cognitive functioning, as well as with sleep quantity and sleep quality. (2) These sleep variables are expected to be related to cognitive functioning and behavioral problems. (3) Sleep variables mediate relations between eveningness, cognitive functioning and behavioral problems.

In no other studies have these mechanisms been investigated so extensively before, taking all these variables into account. Such an extensive investigation will make easier to unravel correlations and possible pathways running from chronotype to daytime functioning. This is not only important for academic achievement, but also for diagnostic processes involving children with behavioral problems. These problems might disappear when the child's sleep-wake rhythm is adjusted.

Method

Participants

Primary schools in both urban and rural areas in the Netherlands were approached to take part in this study. 25% (24 schools) were willing to participate and send out a letter to parents of 2591 children, of which 555 (21%) agreed to participate in the study. The sample included a total of 495 children between 7 and 12 years old (mean age = 10.05; SD = 1.50; 52.3% girls). These children and their parents participated in the first wave of the study. After this data-collection, part of the children were randomly selected to take part in the continuation of the study. Children were allocated, treatment allocation by minimization, to three different time-of-day testgroups (early morning, late morning, and early afternoon) with regard to their age (young vs. old) and chronotype (morning, middle, or evening). This final subsample consisted of 333 children (mean age = 9.97 years; SD = 1.50; 55.3% girls). These children were slightly younger than the unselected children (t = 2.018, p = .044), but in absolute numbers this was only 3 months difference. The selected group consisted of more girls than the unselected children (55.4% vs. 45.9%).

An average score of educational level of the parents served as indicator of socioeconomical status. This score was based upon the scores of both the father and the mother on a 5-category response scale: (a) no education, (b) primary, (c) lower secondary, (d) higher secondary, and (e) tertiary. 80% of the parents had at least completed higher secondary school. Most parents were born in the Netherlands (82%), Suriname (4%) or Turkey (2%), although birth data of 64 parents were missing. Sleep quality, defined by the sleep efficiency index (SEI), ranged from .85 to 1.00, with one exception of .70 in the weekend (for this participant, SEI during weekdays was .92). This indicated that there are no children included which suffer from major sleep efficiency problems (rule of thumb: < .80 is indicative of problematic sleep).

Three children were excluded from the sample based on their estimated full-scale IQ, which was in the deficient range (< 70). All parents and children aged 12 years gave written informed consent. The study was approved by the Ethics committee of the faculty Social Sciences of Leiden University.

Procedures

All parents of the children filled out questionnaires (background information, CBCL, and CCTQ) at home. Children were asked to complete the morningness/eveningness questionnaire for children (VOAK; Vragenlijst Ochtendtype/Avondtype voor Kinderen - Questionnaire Morningtype/Eveningtype for Children). The parents of participants of the second part of the study received an additional questionnaire (CSHQ; Childrens Sleep Habits Questionnaire) and were asked to complete a sleep diary for the duration of one week. Tests (duration 70 min, short break included) were administered individually by trained undergraduate psychologists in a separate room at the child's school, mainly during the week in which parents filled out the sleep diary. General intelligence was estimated with two subtests (Vocabulary and Block design) of the Wechsler Intelligence Scale for Children-III. Information processing was assessed with four subtests of the Amsterdam Neuropsychological Tasks (ANT). Test order was counterbalanced, with either order A or B. Verbal task instructions were given, emphasizing both speed and accuracy of performance. Practice trails were included for each task. The test sessions took place on weekdays (Tuesday, Thursday, or Friday) during the months February to June.

Instruments

Morningness-eveningness. Chronotype of the children was assessed with the Dutch version of the Children's Chronotype Questionnaire (CCTQ). The original questionnaire was constructed by Werner et al. (2009). The CCTQ consists of 10 questions to the parent about the child's time-of-day preference for certain activities and about waking in the morning, based on preceding weeks. Answers are predetermined and presented in a 3 to 5-point scale. The final item asks parents to indicate their perceived child's chronotype on a 5-point scale. Scores are summed, with low scores indicating morningness preference and higher scores eveningness preference. The translated version has not been used in the Netherlands before, but the original version has good psychometric properties (Werner et al., 2009).

Behavioral problems. The Child Behavioral Checklist (CBCL 4-18 years) is a parent-report questionnaire containing 113 items assessing a broad range of emotional and behavioral problems in children (Achenbach, 1991; Verhulst, Van der Ende, & Koot, 1996). Several scores can be derived from the questionnaire, such as internalizing and externalizing problems (broadband scales), total problems and several subscales clustering specific problems (narrowband scales). In the present study, age and gender standardized scores of the two broadband scales and the total problem scores were used, as well as the score of attention problems subscale. The Dutch translation of the CBCL was found to have good reliability and validity in the Dutch population (Verhulst, Van der Ende, & Koot, 1996).

CSHQ. The Children's Sleep Habits Questionnaire is a parent questionnaire for children aged 4 through 12 years, to screen for most common sleep problems (Owens, Nobile, McGuinn, & Spirito, 2000). In a large sample of school-aged children, good psychometric properties were found (Owens, Spirito, & McGuinn, 2000). The total sleep disturbance score is formed by the scores on 33 items, each having a 3-point answer scale (1, 2, 3). A higher score on the total scale is indicative of more sleep problems. Average sleep time of the child during schooldays and during days off were requested to the parents as well.

Sleep diary. The sleep diary was filled out during one week. Parents had to write down the time at which lights went out, the time it took the child to fall asleep, waking times and duration during the night and waking time in the morning. From these data, total sleep duration during each night was calculated and mean total sleep duration was calculated for weekdays and weekend separately. Midsleep point was defined as the mid point between falling asleep and waking in the morning, and was calculated separately for weekdays and weekend. Midsleep point is a measure which is thought to be the best indicator of circadian phase (Werner et al., 2009). Eveningness indeed significantly correlated with midsleep point during weekdays (r = .473, $p < .001$) and weekends (r = .363, $p < .001$), taken the demographic variables into account. Moreover, the phase angle between midsleep point during weekend and waking time during weekdays was calculated as a indicator of the interval between the circadian rhythm and the sleep-wake time. This interval correlated significantly with eveningness ($r = -.183$, p = .004), with evening-types having a shorter interval. To assess stability and variability in midsleep point, the mean standard deviation during one week of sleep was derived from the data. Only participants having data on 3 or more nights were included to calculate stability, which lead to the exclusion of one participant on this variable. One participant had completely stable sleep times during the reported 7 days, which led to a standard deviation of 0. This participant was not excluded of further analyses, since there was no reason to assume false reporting of parents. Moreover, several indicators of sleep quality were included in the sleep diary. These were 5-point scales (--, -, 0, +, ++) on which the parent had to indicate the score applicable to their child, concerning difficulties falling asleep, calm/restless sleep, short/long sleep, feeling rested upon waking up, and mood of the child. Only feeling rested upon waking up was included in the analyses, since this was seen as a measure of sleepiness. An additional measure of sleep quality was the sleep efficiency index, which was defined as the total sleep duration divided by the total time in bed. This measure was calculated separately for weekdays (Sunday night to Thursday night) and weekend (Friday night and Saturday night).

Sleep diary represented normal sleep patterns adequately. The data from the sleep diary correlated highly with those of the sleep habits questionnaire CSHQ, both for schooldays (r = .834, p < .001) and for the weekend (r = .611, p < .001). For the further analyses, sleep variables as measured with the sleep log were used.

Intelligence. To estimate the intelligence of the children, two subtests of the Wechsler Intelligence Scale for Children – Third Edition (WISC-III; Kort et al., 2005) were included in the assessment. These short form, with the subtests ‘Block Design’ and ‘Vocabulary’, has good reliability (r = .91) and validity (r = .85) as an indicator of full-scale IQ with the complete WISC-III (Sattler & Saklofske, 2001). ‘Block Design’ was included in the present study as a measure of non-verbal cognitive reasoning, and ‘Vocabulary’ as a measure of verbal cognitive reasoning.

Information processing. Several informative processing capacities, with the focus on attention, were assessed with three tasks from the ANT (De Sonneville, 1999). Measures of speed (RTs) and accuracy (error rates) served as outcome variables. In tasks in which working memory load was manipulated, performance changes following task manipulation were analyzed.

Simple reaction time was assessed with the *Baseline Speed* task, in which the participant has to detect a stimulus change and has to respond to this as fast as possible by pushing a mouse button. The stimulus is formed by a cross in the center of the screen, which changes to a square at random time intervals. The task consists of a part for the left hand and one for the right hand, each part having 32 presentations. Outcome measure used in the current study is the mean reaction time (RT).

The task *Sustained Attention Dots* is based on a continuous performance paradigm. A participant is presented with three, four, or five dots on a screen and has to push a yes-button is four dots are displayed and the no-button when three or five dots are counted. The task includes 50 series with each 12 presentations in a random order, making the duration of the task about 15-20 minutes. An incorrect response is followed by an auditory signal. Outcome measures in this study are mean series completion time, fluctuation in tempo (within-subject SD of mean completion times of the series), and error rate (amount of misses and false alarms), as well as number of omissions and feedback responsiveness. This last parameter reflects the ability of the child to adjust its behavior in response to feedback, and is operationalized as post-error slowing. After error feedback people are expected to react more carefully and thus slowly than on other trials. Omissions are trails without a response and indicate lapses of attention.

As a measure of focused attention, the task *Focused Attention 4 Letters* was included in the current study. Participants had to detect memorized target consonants (part 1: one consonant, part 2: three consonants) among four presented consonants on a specific diagonal. If the target consonant was present on the predetermined diagonal, the participant has to press "yes". When the target consonant was not present, or present but at the wrong place, the participant has to press "no". Outcome parameters included in the current study are RT and error rate for both part 1 and part 2. This task assesses working-memory capacity as well. Memory load was increased from part 1 to part 2. As measure of working memory, a comparison was made between both RT and error rate difference on part 1 and part 2.

Statistical analysis

First, the data were inspected to check for outliers, missing data and assumptions applying to the statistical tests used, using descriptive statistics, scatterplots, histograms and quantile-quantile plots (Q-Q plots). Variables that did not meet the assumptions for normality were analyzed with non-parametric tests. Demographic variables (age, gender, and SES) were included as covariates in all analyses. Total IQ-score was not included in the analyses as covariate, for reasons discussed by Dennis et al. (2001).

Cases with outliers (z-score ≥ 4 on either a RT-parameter and/or a error-parameter) were removed per task: Baseline Speed: n = 3 (1%); Focused Attention four Letters: n = 35 (11%) and Sustained Attention Dots: n = 12 (4%).

Pearson's and Spearman bivariate correlations between all variables were calculated, to investigate relationships between the variables. Gender differences between the independent variable and dependent variables were assessed with independent *t*-tests. Partial correlations, controlled for demographic variables, were calculated. Univariate and hierarchical linear regression analyses were performed to investigate the ability of an independent variable to predict the dependent variable (above and beyond the effect of the demographic variables). Demographic variables were forced into the first step and independent variables into the second step. In the first analyses, this was done to examine the effect of morningness-eveningness on sleep variables, cognitive variables and behavioral problems. Secondly, the sleep variables were entered as independent variables to assess their effect on cognition and behavioral problems.

Mediation analyses were conducted in order to examine possible intervening effects between an independent and dependent variable. For this, a bootstrapping technique was used as discussed in Preacher and Hayes (2008). This method enables a more thoroughly estimation of the mediation effect and provides confidence intervals, compared to the causal step strategy by Baron and Kenny (1986) and the product-of-coefficients approach with the Sobel-test (Sobel, 1982). Indirect effects can be assessed even when total effects are not present (Hayes, 2009). Bootstapping interval was set to 5000, as suggested by Hayes (2009).

A probability level of p = .05, two-sided was maintained for statistical significance. All analyses were conducted using the Predictive Analytics SoftWare (PASW for Windows, version 17.0, SPSS Inc, 2010).

Results

Descriptive and preliminary analyses

Details on demographic, intellectual, socioeconomic, and psychopathological characteristics of the study sample are provided in Table 1.

Table 1. *Demographic and clinical characteristics.*

	Total (N = 333)
Gender (% girls)	55.3
Age (years)	9.97 (1.50)
SES[a]	
No education	1%
Primary education	2%
Lower secondary education	16%
Higher secondary education	35%
Tertiary education	47%
Eveningness-score	26.14 (5.59)
CBCL total problems[b]	47.27 (10.43)
CBCL internalizing problems[b]	49.49 (10.61)
CBCL externalizing problems[b]	48.21 (9.67)
WISC-III[NL] TIQ[c]	103.79 (14.28)

[a] Familial socioeconomic status, defined by parental educational level.
[b] Standardized *T*-scores.
[c] Very short form: Block Design, Vocabulary

Table 2 presents the bivariate correlations between the main independent and dependent variables. Age was significantly correlated to all sleep variables, except for feeling rested upon waking up during weekdays. Both gender and familial socioeconomic status (parental educational level; SES) correlated with several independent and dependent variables. Gender was significantly related to eveningness score. An independent-sample *t*-test indicated that girls (M = 27.02, SD = 5.74) were more evening-oriented than boys (M = 25.06, SD = 5.21), $t(329) = -3.20$, $p = .001$. Furthermore, parents reported significantly more externalizing problems for boys (M = 49.87, SD = 10.01) than for girls (M = 46.82, SD = 9.17), $t(313) = 2.82$, $p = .005$. A higher SES score was associated with less behavioral problems. In addition,

Table 2. *Bivariate correlations among the demographic variables, sleep, and behavior.*

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Age	-																
2	Gender	.03	-															
3	SES	-.01	.03	-														
4	Eveningness	.28**	.17**	.00	-													
5	Sleep duration weekdays	-.56**	-.10	-.17**	-.31*	-												
6	Sleep duration weekend	-.38**	.04	-.12	-.10	.54**	-											
7	Midsleep point weekdays	.55**	-.01	.08	.55*	-.61**	-.30**	-										
8	Midsleep point weekend	.45**	.05	.02	.45*	-.46**	-.23**	.68**	-									
9	SEI weekdays	-.15*	-.05	-.11	-.28**	.53**	.24**	-.44**	-.25**	-								
10	SEI weekend	-.21**	-.01	-.07	-.18**	.36**	.32**	-.26**	-.06	.58**	-							
11	Feeling rested upon awakening weekdays	-.07	-.09	-.13*	-.33**	.19**	.08	-.31**	-.20**	.32**	.30**	–						
12	Feeling rested upon awakening weekend	-.15*	-.03	-.11	-.20**	.07	.16**	-.17**	-.09	.14*	.27**	.67**	-					
13	Sleep stability MSP	.21**	.06	.01	.16**	-.13*	-.10	.17**	.69**	-.03	.05	-.06	-.07	-				
14	CBCL total	-.03	-.06	-.16**	.14*	.01	.05	.06	.05	-.06	-.07	-.20**	-.17**	.04	-			
15	CBCL internalizing	.04	-.01	-.12*	.14*	-.10	-.02	.08	.03	-.08	-.10	-.19**	-.17**	.00	.85**	-		
16	CBCL externalizing	-.08	-.16**	-.16**	.07	.04	.08	.00	.04	-.00	-.00	-.15*	-.15*	.03	.84**	.61**	-	
17	CBCL attention scale	-.01	-.09	-.10	.05	-.00	.00	.03	.03	-.11	-.11	-.17**	-.10	.05	.71**	.44**	.56**	-

**p* < .05. ***p* < .01.
MSP: Midsleep point

Table 3. *Bivariate correlations among the demographic variables and attention variables.*

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Age	-																	
2	Gender	.03	-																
3	SES	-.01	.03	-															
4	Eveningness	.28**	.17**	.00	-														
5	Verbal intellectual abilities	.65**	.02	.19**	.26**	-													
6	Non-verbal intellectual abilities	.38**	.01	.17**	.06	.53**	-												
7	Baseline Speed RT	-.67**	-.01	-.09	-.16**	-.48**	-.28**	-											
8	Focused att. part 1 RT	-.67**	-.04	-.10	-.40**	-.51**	-.39**	.60**	-										
9	Focused att. part 1 error	-.01	-.05	-.01	.01	.02	-.01	.02	-.09	-									
10	Focused att. part 2 RT	-.62**	-.06	-.08	-.19**	-.44**	-.35**	.55**	.88**	-.07	-								
11	Focused att. part 2 error	-.05	-.13*	-.06	-.00	-.07	-.11	.11	-.01	.56**	.01	-							
12	Working memory RT	-.18**	-.06	-.01	-.02	-.11	-.05	.13*	.19**	.05	.60**	.05	-						
13	Working memory error	-.07	-.09	-.03	.02	-.11	-.10	.08	.08	-.49**	.06	.37**	-.01	-					
14	Sustained att. RT	-.62**	.03	-.11	-.12*	-.47**	-.43**	.56**	.72**	-.12*	.73**	-.09	.32**	.03	-				
15	Sustained att. stability RT	-.54**	-.01	-.17**	-.09	-.44**	-.43**	.50**	.67**	-.02	.71**	.03	.37**	.03	.86**	-			
16	Sustained att. errors	-.02	-.10	-.08	.05	-.04	-.06	.04	-.08	.49**	-.08	.45**	.01	-.04	-.21**	.04	-		
17	Sustained att. omissions	.51**	.05	-.04	-.08	-.39**	-.41**	.41**	.52**	-.00	.53**	.01	.23**	.01	.66**	.71**	.01	-	
18	Sustained att. Feedback Respons.	-.03	.06	-.08	-.01	-.08	-.09	.01	.23**	-.36**	.24**	-.32**	.10	.04	.40**	.30**	-.57**	.13*	-

$*p < .05$. $**p < .01$.
RT: reaction time
Att: attention
Respons: responsiveness

a higher SES score was associated with less sleep during weekdays. To control for possible confounding effects of the important demographic variables, age, gender and SES were included as covariates in the analyses. Consequently, all association numbers reported in the following are partial correlations, corrected for age, gender and SES, unless mentioned otherwise.

Eveningness and cognition/behavior

The bivariate correlations revealed that indeed eveningness correlated with behavioral problems, with children with a higher eveningness score having more behavioral problems, as indicated by their parents. Further analyses showed that only internalizing problems, and not externalizing problems, were associated with a higher score on the morningness-eveningness score. The attention-scale of the CBCL did not correlate significantly with the eveningness. A hierarchical regression analysis was performed next to examine the ability of morningness-eveningness to predict CBCL total score above and beyond the effects of demographic variables. Age, gender, and SES were forced in the first step and eveningness score in the second step of the analysis. Eveningness predicted behavioral problems over and above the effects of demographic variables, $\beta = .17$, $t(303) = 2.95$, $p = .003$. This model ($F(4,303) = 5.16$, $p < .001$) explained 5.1% of the variance in the CBCL total score, which was 2.4% more than the model with only the demographic variables. Moreover, internalizing ($\beta = .14$, $t(308) = 2.44$, $p = .015$) and externalizing ($\beta = .13$, $t(307) = 2.29$, $p = .023$) problem score were predicted by eveningness above and beyond the effect of demographic variables as well. Eveningness was positively associated with verbal cognitive reasoning, $r = .11$, $p = .045$. Eveningness did not significantly correlate with the other cognition variables regarding non-verbal cognitive reasoning, attention, and working memory.

Eveningness and sleep

Sleep duration during schooldays ranged from 483 minutes to 715 minutes (M = 608, SD = 43). During the weekend the range of sleep duration extended, with sleep duration ranging from 463 minutes to 805 minutes (M = 608, SD = 48). Midsleep point during weekdays (M = 68, SD = 28) was significantly different from midsleep point during the weekend (M = 111, SD = 47), $t(252) = 14.32$, $p < .001$. The stability of this midsleep point during one week (within-subject standard deviation) ranged from 0 to 91 minutes ($M = 29$, SD = 16). Midsleep point during weekdays correlated highly with sleep duration during weekdays ($r = -.45$, $p < .001$). This relation was not found for weekends ($r = -.09$, $p = .152$). The sleep efficiency index (SEI) during weekdays correlated significantly with sleep duration during these days ($r = .58$, $p < .001$). Furthermore, an association was found of sleep duration with feeling rested upon waking up during weekdays ($r = .14$, $p = .030$), as for SEI and feeling rested upon waking up ($r = .28$, $p < .001$). SEI during the weekend correlated significantly with sleep duration in the weekend ($r = .31$, $p < .001$). The subjective indicator of sleep quality in this study, feeling rested upon waking up, was not related to sleep duration in the weekend ($r = .09$, $p = .174$) but it was significant correlated with SEI in the weekend ($r = .34$, $p < .001$). Stability of midsleep point was not associated with both the sleep duration and the sleep efficiency parameters. All directions of the significant correlations-coefficients indicated that longer sleep duration and a higher SEI were associated with a more positive rating on the subjective measure regarding sleepiness.

Eveningness correlated with several sleep variables (i.e. quantity and quality), as is presented in Table 2. A significant correlation was found between eveningness and sleep duration during weekdays ($r = -.18$, $p = 0.005$). In weekends, this association between eveningness and sleep duration was not found ($r = -.01$, $p = .944$). Hierarchical linear regression analyses with demographic variables forced in the first step and eveningness-score in the second step indicated that eveningness only predicted sleep duration during weekdays above and beyond the effect of demographic variables ($\beta = -.14$, $t(250) = -2.51$, $p = .013$).

Eveningness did significantly correlate to some of the indicators of sleep quality. A negative association was found between eveningness and the SEI during weekdays ($r = -.23$, $p < .001$) and SEI during weekend ($r = -.16$, $p = .014$). A negative association was found between eveningness and feeling rested upon waking up during weekdays ($r = -.33$, $p < .001$). This association was not found between eveningness and feeling rested upon waking up during the weekend ($r = -.11$, $p = .091$). In addition, feeling rested upon waking up during weekdays correlated with phase-angle, which is an indicator of a discrepancy between circadian rhythm and sleep-wake time (r = .15, p = .021). The directions of the significant associations all indicate that more evening-orientation (higher CCTQ-score) is associated with less quality of sleep.

Sleep and cognition/behavior

Sleep duration.

Partial correlation analyses indicated that verbal cognitive reasoning significantly correlated to sleep duration during weekdays (r = -.22, p < .001) and not to sleep duration during weekend. Non-verbal cognitive reasoning showed similar associations; a significant correlation with sleep duration during weekdays (r = -.14, p = .033) and a non-significant correlation with sleep duration during weekend. Table 4 depicts the partial correlations between sleep duration and the attention and working memory parameters. Overall, only a few significant relations were identified. Series of hierarchical regression analyses, with the demographic variables forced in step 1 and sleep duration parameters entered stepwise in step 2, indicated that only error rate on the working memory task is predicted by sleep duration during weekend (β = .17, t(214) = 2.26, p = .025) above and beyond the effect of the demographic variables.

Table 4. *Partial correlations between sleep duration and cognitive functioning.*

	Sleep duration weekdays	Sleep duration weekend
Baseline speed		
RT	.07	.04
Sustained attention		
RT	-.06	.05
Stability RT	.01	.09
Error % sustained attention	.10	.09
Omissions	.04	-.02
Feedback responsiveness	.02	.02
Focused attention		
RT part 1	.00	.02
Error % part 1	-.06	-.02

RT part 2	-.03	.03
Error % part 2	.12	.14*
Working memory		
RT	-.05	.03
Error %	.19**	.17*

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

Hierarchical regression analyses indicated that the variables regarding sleep duration did not predict CBCL total score (behavioral problems), internalizing or externalizing behavioral problems, or attention problems, above and beyond the effect of demographic variables. In these analyses, demographic variables were forced into the first step and the sleep duration variables into the second step.

Sleep quality.

A significant partial correlation was found for SEI during weekdays and verbal cognitive reasoning (r = -.17, p = .006). The results of the hierarchical regression analyses indicated that sleep efficiency during weekdays did predict performance on verbal cognitive reasoning above and beyond the effect of the demographic variables, (β = -.19, t(241) = -3.12, p = .002). A low verbal cognitive reasoning score is predicted by a higher SEI during weekdays. Non-verbal cognitive reasoning was not significantly predicted by sleep quality parameters.

With regards to simple reaction speed (Baseline Speed), only feeling rested upon awakening in the morning during weekend predicted the performance on this task above and beyond the influence of demographic variables, β = -.11, t(234) = -2.12, p = .035. Feeling more rested upon waking up during the weekend predicted a shorter reaction time. Both reaction time on part 1 (simple) and part 2 (complex) of the focused attention task, as well as the error rates, were not predicted significantly by sleep quality parameters above and beyond the effect of the demographic variables. Feeling rested upon waking up during weekdays predicted reaction time (β = -.15, t(230) = -2.89, p = .004) and stability in reaction time (β = -.14, t(230) = -2.60, p = .010) on the sustained attention task. These results indicated that a higher reaction time and more instability in reaction time were predicted by feeling less rested upon waking up. Reaction time on the working memory task was significantly predicted by feeling rested upon waking up during weekdays (β = -.16, $t(213)$ = -2.38, p = .018), in the direction that a feeling more rested predicted a lower reaction time (e.g. faster response). Sleep quality did not predict working memory error rate.

The ability of sleep quality parameters to predict behavioral problems was analyzed with series of hierarchical regression analyses. Feeling rested upon waking up during weekdays significantly predicted behavioral problems (total CBCL), β = -.23, $t(231)$ = -3.52, p = .001, internalizing problems (β = -.18, $t(234)$ = -2.72, p = .007), externalizing problems (β = -.18, $t(234)$ = -2.79, p = .006) and attention problems (β = -.16, $t(240)$ = -2.50, p = .013) above and beyond the effects of demographic variables. None of the other sleep quality parameters predicted behavioral problems.

Mediation eveningness and cognition/behavior by sleep

To explore several pathways which might play a role in the relation between eveningness and cognition and behavior, mediation analyses were performed with sleep as a mediator between eveningness and cognitive functioning and as a mediator between eveningness and behavioral problems.

Sleep as mediator between eveningness and behavioral problems.

Eveningness was included as independent variable (X), CBCL score as dependent variable (Y), and sleep duration and sleep efficiency parameters as possible mediating variables (Z). Age, gender, and SES were included as covariates. This analysis was repeated for each of the sleep parameters and behavioral problems variables separately.

Only feeling rested upon waking up during weekdays mediated the relation between eveningness and total problem score, internalizing problems, externalizing problems, as well as attention problems. For the broadband scales, this relation can best be described as the indirect effect of eveningness on behavioral problems through feeling rested upon waking up during weekdays, since no significant total effects were found. Results are presented in Table 5 and displayed in Figure 2.

Table 5. *Significant indirect effects of feeling rested upon waking up during weekdays in the mediation analyses between eveningness and behavioral problems.*

		b	*CI*	*t*	*p*
Total problem score	Total effect	.34		2.74	.007**
	Direct effect	.22		1.73	.085
	Total indirect effect	.12	.0408 ; .2233		
Internalizing problems	Total effect	.22		1.76	.081
	Direct effect	.11		.81	.420
	Total indirect effect	.12	.0304 ; .2253		
Externalizing problems	Total effect	.22		1.91	.057
	Direct effect	.13		1.08	.283
	Total indirect effect	.09	.0245; .1873		
Attention problems	Total effect	.06		2.18	.030*
	Direct effect	.04		1.38	.170
	Total indirect effect	.02	.0033 ; .0439		

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

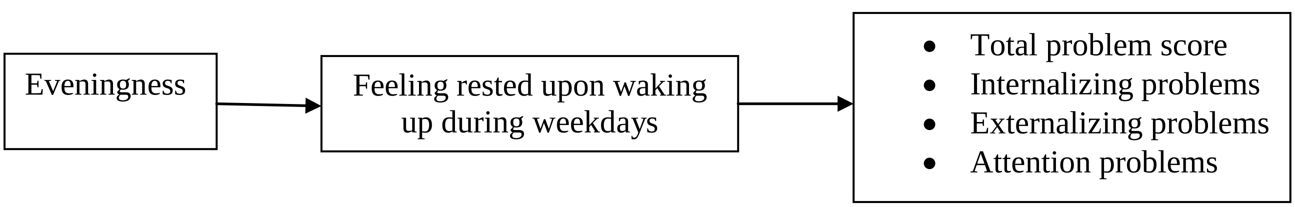

Figure 2. Significant mediation effects in the relation between eveningness and behavior

Sleep as mediator between eveningness and cognitive functioning.

In the relation between eveningness and cognitive functioning, several significant indirect moderation effects were found. These are displayed in Figure 3, and the coefficients and confidence intervals are presented in Table 6 to Table 10.

Table 6. *Significant indirect effects of sleep duration during weekdays in the mediation analyses between eveningness and cognitive functioning.*

		b	*CI*	*t*	*p*
Verbal cognitive functioning	Total effect	.15		2.01	.046*
	Direct effect	.11		1.50	.134
	Total indirect effect	.04	.0074 ; .0907		
Non-verbal cognitive functioning	Total effect	-.10		-.80	.424
	Direct effect	-.14		-1.16	.247
	Total indirect effect	.04	.0048 ; .1132		
Sustained attention errors	Total effect	.37		1.29	.197
	Direct effect	.45		1.57	.117
	Total indirect effect	-.08	-.2385 ; -.0004		

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

Table 7. *Significant indirect effects of sleep efficiency during weekdays in the mediation analyses between eveningness and cognitive functioning.*

		b	*CI*	*t*	*p*
Verbal cognitive functioning	Total effect	.15		2.01	.046*
	Direct effect	.11		1.48	.152
	Total indirect effect	.04	.0092 ; .0966		

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

Table 8. *Significant indirect effects of stability of midsleep point in the mediation analyses between eveningness and cognitive functioning.*

		b	*CI*	*t*	*p*
Verbal cognitive functioning	Total effect	.15		1.99	.048*
	Direct effect	.17		2.21	.028*
	Total indirect effect	-.02	-.0658 ; -.0004		

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

Table 9. *Significant indirect effects of feeling rested upon waking up during weekdays in the mediation analyses between eveningness and cognitive functioning.*

		b	*CI*	*t*	*p*
Working memory RT	Total effect	3.48		1.37	.172
	Direct effect	2.16		.82	.414
	Total indirect effect	1.32	.0991 ; 3.0679		
Sustained attention RT	Total effect	.06		1.47	.144
	Direct effect	.03		.61	.540
	Total indirect effect	.03	.0093 ; .0725		
Sustained attention stability RT	Total effect	.02		1.46	.147
	Direct effect	.01		.78	.434
	Total indirect effect	.01	.0003 ; .0195		

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

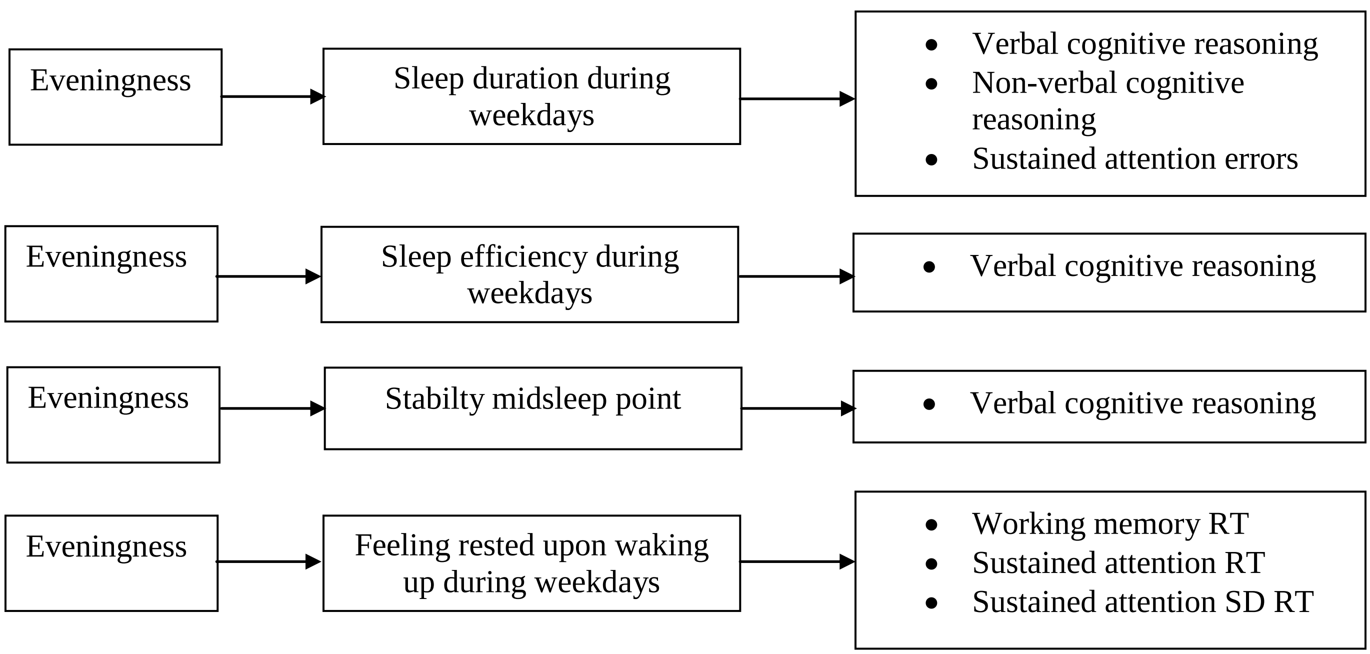

Figure 3. Significant mediation effects in the relation between eveningness and cognitive functioning.

Discussion

In this study we aimed to evaluate the relation between eveningness, sleep variables, cognitive measures, and behavioral problems. Recent studies found that children showing an eveningness preference display more behavioral problems. However, to date it is still unknown which pathways are at the root of these relation. One of the hypotheses in this study was that sleep quantity and sleep quality might mediate the relation, since eveningness is associated with less sleep and increased sleep variability. Moreover, other studies have also indicated that cognitive functioning can be influenced by sleep quantity and/or quality. Therefore, several measures of cognitive functioning, especially attention, were also included as outcome measures here. This study is new in that it explores a variety of relations between these important areas and tries to provide insights into possible pathways by which these processes might take place. The results of the present study confirm the main hypothesis, i.e., that circadian preference (morningness-eveningness) partly predicts behavioral problems. Children with a preference towards eveningness showed more internalizing and externalizing behavioral problems than children showing a preference towards morningness, as reported by their parents. This is in line with recent study results that demonstrated that these children and adolescents are more often reported as showing behavioral problems (Gianotti et al., 2002; Gau et al., 2007; Goldstein et al., 2007; Paavonen et al., 2009; Lange & Randler, 2011). However, previously reported associations of eveningness with ADHD-related symptoms of inattentiveness could not be replicated (Caci, Bouchez, & Baylé, 2009; Paavonen et al., 2009). In the relation between chronotype and cognitive functioning we found a significant positive association only with verbal cognitive reasoning was found. This contradicts the hypothesis that eveningness is associated with lower cognitive functioning. How this might be explained will be discussed below.

Eveningness & sleep

This study was aimed at exploring which aspects of sleep play a role in the relation between chronotype on the one hand, and cognition and behavior on the other. An individuals' circadian preference can have a direct influence on two different, but associated, aspects of sleep: quantity and quality. We hypothesized that evening types experience less sleep during weekdays. Moreover, we also expected sleep quality to be affected, since for instance evening types are thought to experience more variability in their sleep pattern. Both these hypotheses were confirmed by the results of this study. Eveningness significantly predicted sleep duration during weekdays, but not during weekends. This is in line with results from previous studies regarding this area of interest (Taillard et al., 1999; Russo et al., 2007). During weekdays, evening types go to sleep later in the evening and still have to get up at approximately the same time as morning types due to the school schedule. Wittmann, Dinich, Merrow and Roenneberg (2006) described this misalignment of biological rhythm and social rhythm as a 'social jet-lag'. During the weekend persons showing an eveningness preference try to reduce the sleep debt they developed during weekdays, by extending their sleep duration. Eveningness significantly correlated with midsleep point both during weekdays and the weekend. Midsleep point is considered a reliable measure of circadian phase (Werner et al., 2009), and showed a strong correlation with sleep duration during weekdays, but not during weekends. This confirms the idea that during weekdays a late sleep-wake rhythm might lead to shorter sleep, but not in the weekend, since people can choose their own time to wake up.

Evening orientation is associated with lower sleep quality, as shown by the sleep efficiency indices. Sleep efficiency might be less in children showing an eveningness preference, since during weekdays these children have to go to bed earlier than they would prefer, and therefore do not experience much sleep pressure at bedtime. This makes that their time in bed relative to their sleep duration is longer than for children showing a morningness preference. During the weekend sleep efficiency might be suppressed by the relatively high activity shown by evening types in the hours before they go to bed. Moreover, evening types are characterized by longer sleep latency (Kerkhof, 1991; Gaina et al., 2006). As a consequence, they spend more time awake while in bed and therefore have a lower sleep efficiency. Eveningness is associated with feeling less rested upon waking up during weekdays as well. Gaina et al. (2006) found similar associations in adolescents aged 12 to 15 years, with morning types reporting feeling better in the morning. An explanation for this might be that during weekdays evening-type children have to rise earlier than the time preferred by the rhythm of their biological clock because of the constraints of the social rhythm, and consequently experience a social jet-lag (Wittmann et al., 2006). This idea may be confirmed by our finding that the period between midsleep point and rising time during weekdays is shorter for evening types than for morning types.

Sleep duration

Sleep duration during weekdays predicted verbal and non-verbal cognitive reasoning, in the sense that longer sleep duration was predictive of lower cognitive functioning. This is not the direction we expected, since we had hypothesized that longer sleep duration would predict higher cognitive functioning. For example, Gruber et al. (2010) found that longer sleep duration was associated with better intellectual performance. However, the results are in line with a recent study by Geiger et al. (2010), who found a negative association between sleep duration and IQ score in children aged 7 to 11 years. They propose that these unexpected results may be explained by the neural efficiency theory (Haier, 1988). They expanded this theory to nighttime behavior, with children having a higher daytime (cognitive) efficiency being more efficient during nighttime as well, resulting in shorter sleep duration. Another explanation proposed by Geiger et al. (2010) is that children who sleep less benefit from the longer wake time, with for instance more cognitive stimulation. However, if these explanations hold one would also expect to find associations between sleep duration during the weekend and cognitive reasoning, which was not the case in this study. So, specific aspects associated with only sleep duration during weekdays are expected to explain this relation. The results showed that longer sleep duration during the weekend predicts more errors on a working memory task. This contradicts the findings of Steenari et al. (2003), who found a negative association between sleep duration and performance on high-load working memory tasks in children. Interestingly, sleep duration did not predict attention. It was expected that shorter sleep duration would influence a child’s ability to focus and sustain attention, since these relations have been frequently reported for adults (Pilcher & Huffcutt, 1996, Van Dongen, Maislin, Mullington, & Dinges, 2003; Blatter & Cajochen, 2007). This might be explained by the lack of participants experiencing sleep deprivation. Although sleep duration differed between children, each individual could experience adequate sleep and therefore not show impaired performance on attention tasks. Another explanation may be that sleep deprivation in children does not influence their performance on attention tasks as much as it does in adults, since the associated brain areas (attention networks) are not fully developed yet (Astill et al., 2011).

Contrary to expectations behavioral problems were not predicted by measures of sleep duration. Most previous studies did find an association between these variables (Touchette et al., 2007; Paavonen et al., 2009; Pesonen et al., 2011), although Gruber (2010) found no relation either. The lack of results was attributed to the fact of having participants that were not sleep-deprived. That might hold for our sample as well, although this aspect was not assessed directly in this study. Another explanation might be that parents may be unaware of behavioral problems, since these are often more evident at school. This corresponds to findings by Aronen et al. (2002), who found associations between sleep duration and teacher-reported behavioral problems, but not between sleep duration and parent-reported problem behavior. Overall, sleep duration was found to be only partly associated with cognitive functioning, and not with behavioral functioning.

Sleep quality

Sleep efficiency during weekdays is negatively associated with verbal cognitive reasoning. Just as with sleep duration, we did not expect the relation to run in this direction. Feeling more rested upon waking up during weekends predicted a faster simple reaction time. This finding indicates that performance is best after sleeping in concordance with one's circadian rhythm. Feeling rested upon waking up during weekdays predicted sustained attention reaction time, sustained attention stability in reaction time, working memory reaction time. Thus, this measure of subjective sleepiness indicates that several cognitive measures are affected by not feeling rested upon waking up during weekdays, in line with results found by Sadeh et al. (2002) and Anderson et al. (2009). This means that sustained attention as well as working memory are influenced by sleepiness on weekdays. This is especially important in view of the fact that these are schooldays. No results were found for focused attention. In addition, feeling rested upon waking up during weekdays was associated with behavioral problems.

Children feeling more rested in the morning showed fewer behavioral problems. We expected variability of sleep pattern to be related to behavioral problems as well (Pesonen et al., 2011), but no significant associations were found. It might be that variability of sleep patterns was not large in this sample of school-age children.

Mediation

Our next hypothesis was that the aspects of sleep discussed earlier could have a mediating role in the relation between eveningness on the one hand, and cognitive and behavioral functioning on the other. The main finding of the mediation analyses is that evening types show behavioral problems when they do not feel rested upon waking up in the morning during weekdays. For these individuals their circadian rhythm is far behind their sleep-wake rhythm, as was indicated by the phase angle. The small phase angle in these individuals indicates that these persons wake up earlier on weekdays than preferred given their circadian rhythm, which might cause them to wake up not rested. By means of electroencephalography (EEG) differences have been found between morning and evening types in markers of homeostatic sleep regulation. The decrease in sleep pressure during sleep in evening-type persons takes place more slowly than in morning-type persons (Mongrain, Carrier, & Dumont, 2006). So, although sleep duration is equal in both extreme circadian types, it might be that evening types wake with more sleep pressure remaining. This means that during daytime their sleep pressure could be higher, which might influence cognitive and behavioral functioning. In the relation between eveningness and behavioral problems no indirect effect of sleep duration was found. A reason for this might be that no relation between sleep duration and behavioral problems was found. Of the sleep quality indicators, only feeling rested upon waking up during weekdays significantly mediated the relation between eveningness and behavioral problems. This might be explained by the fact that all these variables are based on parental reports. However, an association between feeling rested upon waking up during weekdays and cognitive functioning has also been identified. This sleep quality variable was found to mediate the relations between eveningness and working memory reaction time, and between eveningness and sustained attention reaction time and stability in reaction time. Performance on these cognitive variables is associated with sleepiness, which makes this a rather obvious finding. Other indirect effects of sleep duration during weekdays, sleep efficiency during weekdays, and stability of MSP on verbal cognitive reasoning were identified. Lastly, sleep duration during weekdays was found to mediate the relations between eveningness and non-verbal cognitive reasoning and sustained attention error rates. Therefore, it seems that it is especially measures of sleep during weekdays, on which the sleep-wake rhythm in evening-type persons does not match their circadian rhythm, that is associated with cognitive and behavioral functioning.

The results indicate that most likely it is not only sleep that affects the relation between eveningness on the one hand, and behavioral and cognitive functioning on the other. Which other factors might explain this relation has not been clarified yet. This relation might be mediated by for instance personality and temperament. Evening-type persons are identified as being more extravert, impulsive, novelty and sensation seeking, and having lower scores on cooperation, conscientiousness, and agreeableness (Randler, 2008; Tonetti et al., 2010; Randler & Saliger, 2011). Most of these traits are associated with more behavioral problems or less desirable behavior in society. Another explanation might be that the cognitive-behavioral problems in children with an evening preference are part of the symptoms of psychiatric disorders such as ADHD. Eveningness is seen more frequently among ADHD patients (Caci, Bouchez, & Bayle, 2009). In addition, behavioral symptoms associated with ADHD are overlapping with behavioral characteristics associated with eveningness. For instance, Gianotti et al. (2002) reported an association between eveningness and attention problems. Moreover, impulsivity is associated with eveningness as well (Caci et al., 2005). In this study only three children with a diagnosis of ADHD were included. Compared to the total sample size, this number of ADHD-participants was too small to analyze separately. Furthermore, parents of evening-oriented children might be biased in the reporting of behavioral problems. When children do not want to get to bed in time in the evening and have a hard time waking up in the morning, there might be a constant struggle at home. This might bias parents in rating their child’s behavior, and form an underlying mechanism in the relation between eveningness and behavior. However, Gau et al. (2007) also found a relation between eveningness and behavior for adolescents using self-reports.

It must be mentioned that in this study we explored correlations between variables, and that there is not necessarily a causal relation between the variables analyzed. It might be that impaired cognitive and behavioral functioning affects sleep-wake times, in the direction of less sleep and lower sleep quality, by which persons are identified as tending more towards the evening type. When experiencing impaired daytime functioning people might have trouble falling asleep, for instance due to excessive worrying (internalizing problems) or hyperactivity (externalizing problems). However, there have been several studies on the effect of shifting the biological clock and the effect of this on behavioral and cognitive functioning. Shifting the biological clock was tried in various ways by interventions such as chronotherapy, bright light therapy (BLT), and melatonin treatment. In a case study, Gruber, Grizenko, and Joober (2007) report on a boy whose sleep, cognitive performance, and behavioral functioning improved after one week of BLT. Szeinberg, Borodkin, and Dagan (2006) report on melatonin treatment involving adolescents, and found improved sleep as well as a decrease in difficulties at school. In contrast, another study showed that sleep duration improved after melatonin treatment, but this did not result into improved cognitive and behavioral functioning (Van der Heijden, Smits, Van Someren, Ridderinkhof, & Gunning, 2007). Moreover, Sadeh et al. (2003) found an improved performance on tasks regarding working memory and sustained attention in children who extended their sleep. These results point to an influence of sleep on daytime functioning.

The strengths of our study are the relatively large sample size, the use of well-validated, standardized instruments, and the wide exploration of possible relations. However, in the interpretation of the results some limitations of this study should be noted. First, the data on the various aspects of sleep were derived via a sleep log and questionnaires, not via physiological measures such as actigraph or polysomnigraphy. Although there is a high correlation between the data from the sleep log and those from the questionnaire, they might have been influenced by subjective opinions. However, practical value is of importance here. Morning and evening types as observed in daily life (which is the focus of the CCTQ) has a larger ecological validity than determining eveningness via physiological measures, since it is of great importance to know how people experience their circadian preference. Secondly, the CCTQ has not been validated for the Dutch population. Therefore, no cut-off scores could be used, and the scores were analyzed as a continuum. Moreover, in this study we did not take into account school context such as academic achievement or teacher-rating on behavioral problems.

Implications & conclusion

To conclude, in this study we found a relation between eveningness and behavioral problems, which was partly explained by the indirect effect of feeling rested upon waking up during weekdays. Cognitive functioning was not directly associated with eveningness. Sleep duration was only slightly associated with cognitive functioning, and not with behavioral functioning. Sleep quality, specifically feeling rested upon waking up during weekdays, was associated with cognitive and behavioral functioning. Feeling rested upon waking up during weekdays had an indirect effect on several relations between eveningness and cognitive-behavioral functioning.

Given the impact of eveningness on behavioral functioning it is important to screen for eveningness preference in clinical practice, since this might be a cause of behavioral problems in children. Moreover, we found a significant relation between children's physical health, as reported by parents, and eveningness. A higher eveningness orientation was associated with lower physical health. This might indicate that children's circadian preferences can have an impact on their physical health. Findings of a study conducted by Randler (2011) support this idea. This study found positive correlations between morningness and physical and mental health, with higher scores for adolescents showing a morningness preference. However, since nothing can be said about causality, the relation can also be the other way around. Though, this relation emphasized the importance of screening for eveningness orientation in children's health care. Future research should focus on identifying possible mediators, other than sleep, in the relation between eveningness and daytime functioning, In addition, it is important to determine what role interventions can play in attempts to turn around cognitive and behavioral problems in relation to eveningness.

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