Sleep problems and their implications from preschool to school age

Petteri Simola

Cognitive Brain Research Unit
Cognitive Science
Institute of Behavioural Sciences
University of Helsinki
Finland

and

The Department of Child Psychiatry
University of Helsinki, and
Children's Hospital
Helsinki University Central Hospital
Finland

and

Pediatric Graduate School, Children's Hospital
Helsinki University Central Hospital and University of Helsinki
Finland

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Supervisors: Professor Eeva Aronen
Institute of Clinical Medicine, Department of Child Psychiatry
University of Helsinki
& Children's Hospital, Helsinki University Central Hospital, Finland

Professor Teija Kujala
Cognitive Brain Research Unit
Cognitive Science
Institute of Behavioural Sciences
& Cicero Learning
University of Helsinki, Finland

Reviewers: Professor Emerita Irma Moilanen
Institute of Clinical Medicine, Department of Child Psychiatry
University and University Hospital of Oulu, Finland

Research Professor Mikael Sallinen
Agora Center, University of Jyväskylä
& Center of Expertise for Development of Work and Organizations
Finnish Institute of Occupational Health, Finland

Opponent: Professor Hanna Ebeling
Institute of Clinical Medicine, Department of Pediatrics,
Clinic of Child Psychiatry
University and University Hospital of Oulu, Finland

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Abstract

Sleep plays a significant role in human functioning and wellbeing. It is of particular importance for young children, whose brains undergo significant developmental changes. This dissertation focuses on sleep problems among preschool-age children, the persistence of these problems until school age, and how they relate in establishing a behaviour and emotional wellbeing at school age. The importance of sleep quality to neural basis of sensory information processing and attention regulation among school age children was also assessed.

According to the results of a population-based survey, sleep problems are very common in preschool-age children. Parents of almost half of the children surveyed reported frequent sleep problems most typically resistance to going to bed and difficulties falling asleep, followed by snoring, bruxism and sleep talking. Frequent bedtime resistance and difficulties falling asleep were also reported in a follow-up study of school-age children, as well as difficulty getting out of bed in the morning and early morning fatigue. Overall, the frequency of sleep difficulties decreased at school age. However, more than a third of the preschool-age children with sleep difficulties continued to have such problems at school age, when they were at the highest risk of experiencing comorbid emotional and behavioural problems. On the other hand, only a few children developed sleep problems at school age. Sleep quality among school-age children, measured objectively by means of actigraphy was associated with event-related brain potentials reflecting auditory information processing and attention regulation. Children with lower sleep quality had enhanced N2 and mismatch negativity responses, presumably reflecting hypersensitive reactivity to sounds, compared with children who sleep well.

Sleep problems, therefore, appear to be a major challenge for the wellbeing of children at preschool and school-age. It appears from the results of this study that such problems are more common in younger age group, and that few children develop them later on. Therefore, preschool-age children and their families should be a major target group in identifying and treating sleep problems. It is essential to attend to such problems at preschool-age so as to prevent them from persisting over the longer term and adversely affecting the development of brain functions and behavioural and socio-emotional regulation.

Tiivistelmä

Unella on merkittävä rooli ihmisen toiminnan ja hyvinvoinnin kannalta. Erityisesti unen merkitys korostuu lapsilla, joiden aivot käyvät läpi merkittäviä kehitysvaiheita. Tässä väitöskirjassa tarkastellaan alle kouluikäisten lasten unihäiriöitä, niiden pysyvyyttä kouluikään saakka, yhteyttä psyykkiseen hyvinvointiin kouluiässä, sekä unen laadun merkitystä kouluikäisten lasten varhaisen tason sensorisen informaation käsittelyyn ja tarkkaavaisuuden suuntaamiseen aivotoiminnan tasolla.

Väitöskirjan epidemiologisessa seurantatutkimuksessa havaittiin uniongelmien olevan hyvin yleistä alle kouluikäisillä lapsilla. Vanhemmat raportoivat toistuvia uniongelmia melkein puolella 3-6-vuotiaista lapsista. Yleisimmät ongelmat olivat nukkumaan menemisen vastustaminen ja nukahtamisvaikeudet, mutta myös kuorsaaminen, hampaiden narskuttaminen ja unessa puhuminen olivat yleisiä. Myös kouluiässä nukkumaan menoon liittyvä vastustus ja nukahtamisen vaikeudet olivat yleisiä, kuten myös aamuaikainen väsymys ja vaikeudet nousta sängystä. Kokonaisuudessaan univaikeudet vähenivät kouluiässä. Reilulla kolmanneksella 3-6-vuotiaista lapsista, joilla esiintyi uniongelmia alle kouluikäisinä, esiintyi uniongelmia vielä kouluiässä. Erityisesti näillä lapsilla oli erittäin suuri riski tunne-elämän ja käyttäytymisen ongelmien esiintymiseen univaikeuksien rinnalla. Sen sijaan vain harvalla lapsella uniongelmia alkoi esiintyä enää kouluiässä. Kouluikäisten lasten objektiivisesti mitatulla unen laadulla oli yhteys aivojen herätevastetutkimuksella mitattuun aivojen kuuloinformaation käsittelyyn ja tarkkaavaisuuden häiriöherkkyyteen. Lapsilla, joilla unen laatu oli heikentynyttä, esiintyi aivojen yliherkkään reagointiin viittaavaa aisti-informaation käsittelyn ja tarkkaavaisuuden säätelyn ongelmaa.

Uniongelmien voidaan siis todeta olevan merkittävä haaste alle kouluikäisten ja kouluikäisten lasten hyvinvoinnille. Koska nyt tehdyn tutkimuksen perusteella alle kouluikäisillä uniongelmien esiintyvyys on selkeästi suurempaa kuin kouluikäisillä, tulisi neuvoloiden roolia univaikeuksien tunnistamisessa ja hoitamisessa kehittää entisestään. On tärkeää, että pienten lasten uniongelmat eivät muuttuisi pysyviksi, koska erityisesti pitkäkestoisina ne voivat haitata lapsen aivotoiminnan, käyttäytymisen ja sosioemotionaalisen säätelyn kehittymistä.

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"*Don't worry, sleep problems are common in young children, they will go away when the child grows!*" This kind of statement is to be heard not only in normal conversations, but also among professionals. What if it is not true and only something that we parents merely wish to believe during the nights we stay awake with our child?

I express my deepest gratitude to my supervisors Professor Eeva Aronen and Professor Teija Kujala for their excellent guidance, advice and support during all these years. It has been a privilege to witness not only their academic professionalism, but also their enthusiasm and passion for their work. I wish to thank my co-authors for their exceptional input to our research, my current employer Professor Jukka Leskinen who always valued my academic passion and Docent Lauri Oksama who understood my anxieties when I was writing this thesis. I also wish to thank my co-workers at the Human Performance Division of Finnish Defence Agency, with special thanks to Satu Arola for her help during the final process of writing this thesis. Also I wish to thank Jari Lipsanen, Tommi Makkonen, and Miika Leminen for their methodological help and guidance.

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Last, but not least I thank my parents, relatives and friends I am especially grateful to my mother, my wife Kaisa, the love of my life who has always believed in me, especially during the days when I have not, and my children Eemeli, Otava, and Kerttu who truly do give me the strength and determination to reach out and go further. And yes "Daddy's never-ending project" as you so kindly refer to my doctoral study, is finally finished.

Helsinki, May 6th 2014

Petteri Simola

List of original publications

This thesis is based on the following publications, which are referred to in the text by their Roman numerals.

I. Simola, P., Niskakangas, M., Liukkonen, K., Virkkula, P., Pitkäranta, A., Kirjavainen, T., & Aronen E. T. (2010). Sleep problems and daytime tiredness in Finnish preschool age children-a community survey. *Child: Care, Health and Development*, *36*, 805–811.

II. Simola, P., Laitalainen, E., Liukkonen, K., Virkkula, P., Kirjavainen, T., Pitkäranta, A., & Aronen, E. T. (2011). Sleep disturbances in a community sample of children from preschool to school age. *Child: Care, Health and Development*, *38*, 572–580.

III. Simola. P., Liukkonen, K., Pitkäranta, A., Pirinen, T., & Aronen, E. T. (2014) Psychosocial and somatic outcomes of sleep problems in children: a 4-year follow-up study *Child: Care, Health and Development*, *40*, 60–67.

IV. Simola. P., Kujala, T., Salmi, J., Huotilainen, M., Pakarinen, S., & Aronen, E. T. Effects of natural variation in sleep quality on low-level auditory processing in children. *Submitted.*

Abbreviations

AASM	American Academy of Sleep Medicine
ANOVA	analysis of variance
AI	apnoea index
BAEB	brainstem auditory evoked potentials
CBCL	child behaviour checklist
CI	confidence interval
DSM IV/V	diagnostic and statistical manual of mental disorders IV/Vth edition
EEG	electroencephalography
EKG	electrocardiography
EOG	electro-occulogram
ERP	event-related potentials
ICD-10	international classification of diseases 10th edition
ICSD-2	international classification for sleep disorders, second edition
LM	left mastoid
LLAEP	long-latency auditory evoked potentials
MMN	mismatch negativity
MLAEP	middle-latency auditory evoked potentials
ns	non-significant
nREM	non-rapid eye movement
OSAS	obstructive sleep apnoea syndrome
OR	odds ratio
REM	rapid eye movement
RM	right mastoid
SD	standard deviation
SDSC	sleep disturbance scale for children
SE	standard error
SES	socioeconomic status
SWS	slow wave sleep

1. Introduction

1.1 Sleep

1.1.1 Circadian rhythm and sleep

Sleep has a significant role in human behaviour and wellbeing. It is, in particular, essential for children undergoing significant developmental changes through childhood and adolescence. Even though sleep is known to be vital for development, memory consolidation, physiological restoration, and overall wellbeing (Astill, Van der Heijden, Van Ijzendoorn, & Van Someren, 2012; Dahl, 1998; Jan et al., 2010; O'Brien, 2009; Walker & Stickgold, 2006), its exact function remains elusive (Walker & Stickgold, 2006), and mechanisms that underlie the negative effects of sleep problems are not clearly understood.

During the first years of life humans develop a rather robust cycle of sleep and wake periods that is called the circadian rhythm. In fact, most infants exhibit some regularity during the first year of life (A. Scher, 2012), even though the parental hope of continuous sleep is often a mere daydream. The human circadian rhythm can be divided into diurnal active and nocturnal resting or sleep periods. Among preschool children the diurnal active period often includes one or two naps. Sleep is often said to be a naturally recurring state characterised by reduced or absent consciousness, relatively suspended sensory activity, and inactivity of nearly all voluntary muscles. This is true but sleep is much more than a state of inactivity and immobility.

Polysomnography (PSG) studies have revealed that the brain is active, and that the activity changes during sleep. PSG simultaneously records several variables such as electroencephalography (EEG), electrocardiography (EKG), and electro-occulogram (EOG) respiratory and blood pressure. Findings from PSG studies indicate that sleep can be divided into four different stages[1]. The first three stages are often referred to as non-REM (nREM) stages and stage four as the rapid eye movement (REM) stage, these stages alternate across the night in adults in a 90-minute cycle, whereas in children the cycle is faster and slows down during maturation (Walker & Stickgold, 2006; Šušmáková, 2004). The first stage (nREM stage 1) is a transition stage between

[1] Sleep stages were previously categorised into five stages (stages I-IV nREM and stage V REM)

wakefulness and sleep and is characterised by alpha activity. The second stage (nREM stage 2) is characterised by theta activity, and is often interrupted by activity known as sleep spindles and K-complexes which are bursts of oscillatory brain activity and sudden increases in wave amplitude. The third stage (nREM stage 3), often referred to as Slow Wave Sleep (SWS) is the deepest of the nREM sleep stages and includes slow delta activity. Brain activity is complex in the fourth stage (REM stage) and unlike in the nREM stages resembles much day-time brain activity, with a combination of alpha, beta and desynchronous waves. Most dreams occur in the REM stage (Šušmáková, 2004). There are changes other than in the length of the sleep cycle as children develop. Fifty per cent of the sleep of infants is REM sleep whereas in adults the proportion is only 20 per cent and nREM 80 per cent of the sleep cycle (Šušmáková, 2004). Moreover, the maximal slow wave activity shifts from posterior to anterior scalp regions from early childhood to late adolescence. It is believed that this rostral shift toward the frontal cortex is associated with cortical maturation (Kurth et al., 2010).

1.1.2 Factors that predispose to sleep disorders

Children suffer from sleep problems for several reasons, which are attributable to both internal and external factors. Internal factors are related to the psychological or physiological state or developmental stage of the child. Temperament describes the way in which people approach and reacts to the world. It is considered innate and may be related to sleep problems, which are more prevalent in children who are intense and exhibit low adaptability and rhythmicity (Hayes, Parker, Sallinen, & Davare, 2001). In addition, several medical states predispose children to sleep problems. Both acute and chronic disease states (e.g., juvenile rheumatoid arthritis, asthma, and cancer) are known to increase the risk (Lewandowski, Ward, & Palermo, 2011). In many cases the association between sleep problems and medical conditions is often related to underlying disease-related mechanisms (e.g., airway restriction, inflammation), treatment regimens (including medication), or hospitalisation (Lewandowski et al., 2011). Sleep problems also tend to occur in children with neurodevelopmental disorders such as autism spectrum disorders (Paavonen, Nieminen-von Wendt, Vanhala, Aronen, & von Wendt, 2003).

Family-related factors influence sleep too. The way in which parents handle sleep-related routines and night-time waking and interaction quality between the parent and the child are related to the sleep of the children. Parental wellbeing (e.g., depression) as well as external stressors such as work and marital tension are also reported to be associated with sleep problems in children (Keller & El-Sheikh, 2011; A. Scher & Blumberg, 1999; Touchette et al., 2005).

1.1.3 Sleep problems in children

Sleep problems are not restricted to difficulties in falling asleep or maintaining sleep. There are several recognised separate and sometimes comorbid causes, the recognition and understanding of which are essential when treatment is being considered. If the nature and causal mechanisms of sleep problems are not gully understood it is difficult to prescribe effective treatment.

Children are susceptible to various sleep problems which change as they develop. Difficulties falling asleep, night-time waking, and sleep terrors are known to decrease with age (Ottaviano, Giannotti, Cortesi, Bruni, & Ottaviano, 1996; Petit, Touchette, Tremblay, Boivin, & Montplaisir, 2007; Shang, Gau, & Soong, 2006), for example, whereas the incidence of bruxism increases (Hall, Zubrick, Silburn, Parson, & Kurinczuk, 2007). However, most of the age effects on sleep have been found in cross-sectional studies and conclusions have been made by comparing different populations in different age groups. Longitudinal studies determining changes in the phenotype of sleep problems in the same individuals are still rare.

Some studies have reported that boys are more likely to have sleep-related difficulties than girls (Archbold, Pituch, Panahi, & Chervin, 2002; Paavonen et al., 2000; Shang et al., 2006). Further, findings from a Finnish study among pre-adolescents and adolescents suggest that girls experienced more dreaming and night waking, but boys snore more (Saarenpää-Heikkilä, Rintahaka, Laippala, & Koivikko, 1995). Biological factors such as higher pubertal status among girls and social factors may have stronger detrimental effects on boys than on girls. However, not all studies report significant differences between boys and girls in the amount and quality of sleep (Blunden et al., 2004; Neveus, Cnattingius, Olsson, & Hetta, 2001; A. Scher, Zukerman, & Epstein, 2005).

1.1.4 Diagnostic criteria

There have been several attempts to develop comprehensive diagnostic criteria for childhood sleep problems. Commonly used criteria (ICD-10 and DSM-IV/DSM-V) are effectively used to diagnose problems in adults, but are not completely suitable for diagnosing them in childhood. The international classification for sleep disorders (ICSD-2) developed by the American Academy of Sleep Medicine (AASM) is therefore often used with children (American Academy of Sleep Medicine, 2005). ICSD-2 categorises sleep problems into eight main types: 1) insomnia; 2) sleep-related breathing disorders; 3) hypersomnias of central origin not due to a circadian rhythm sleep disorder, sleep-related breathing disorder or other reasons for disturbed nocturnal sleep; 4) circadian rhythm sleep disorders; 5) parasomnias; 6) sleep-related movement disorders; 7) isolated symptoms, apparently normal variants and unresolved issues; and 8) other sleep disorders. Table 1 gives examples of disorders in each category.

1.1.5 Measurement

Several methods serving both for scientific and clinical purposes have been developed in order to determine and diagnose sleep problems. Sleep questionnaires are the most common method used among large populations: they are easy to administer, and if properly used, are a valid and sound method (Bruni et al., 1996; Owens, Spirito, & McGuinn, 2000). Such questionnaires lack nevertheless the accuracy of quantitative/objective assessment by means of actigraphy and polysomnography for example, and are always subjective in nature. With a large samples of young children however, parental reporting usually yields the only available and useful information when limitations are taken into account (Gregory et al., 2011). It has been pointed out that relying only on parental reports may result in the underestimation of possible sleep problems in some cases (Paavonen et al., 2002).

__Table 1.__ ICSD-2 categories and examples of sleep disorders in each category

Category	Sleep disorder
1. Insomnia	Adjustment Insomnia Psychophysiological Insomnia Paradoxical Insomnia Idiopathic Insomnia
2. Sleep related breathing disorders	Primary Central Sleep Apnea Central Sleep Apnea Due to Cheyne Stokes Breathing Pattern Central Sleep Apnea Due to Medical Condition Not Cheyne Stokes Central Sleep Apnea Due to Drug or Substance Obstructive Sleep Apnea, Pediatric
3. Hypersomnias of central origin not due to a circadian rhythm sleep disorder, sleep related breathing disorder, or other cause of disturbed nocturnal sleep	Narcolepsy With Cataplexy Narcolepsy Without Cataplexy Narcolepsy Due to Medical Condition Narcolepsy, Unspecified
4. Circadian rhythm sleep disorders	Circadian Rhythm Sleep Disorder, Delayed Sleep Phase Type Circadian Rhythm Sleep Disorder, Advanced Sleep Phase Type Circadian Rhythm Sleep Disorder, Irregular Sleep-Wake Type Circadian Rhythm Sleep Disorder, Free-Running Type
5. Parasomnias	Confusional Arousals Sleepwalking Sleep Terrors Nightmare Disorder
6.Sleep related movement disorders	Restless Legs Syndrome Periodic Limb Movement Disorder Sleep Related Leg Cramps Sleep Related Bruxism
7. Isolated symptoms, apparently normal variants, and unresolved issues	Long Sleeper Short Sleeper Sleep Talking Sleep Starts
8. Other sleep disorders	Other Physiological (Organic) Sleep Disorder Other Sleep Disorder Not Due to Substance or Known Physiological Condition Environmental Sleep Disorder

Polysomnography, often referred to as the “gold standard” of sleep study gives more comprehensive and accurate evaluation of sleep quality and potential sleep problems. Polysomnography is the comprehensive recording of several biophysiological changes that occur during sleep. It is usually administered in sleep laboratories, but modern portable devices allow recording to be carried out in natural surroundings (i.e. the home). The measures are standardised and guidelines for good practice are provided (Kushida et al., 2005). Whereas polysomnography tends to be used in clinical practice, actigraphy is commonly used in scientific research as an objective measure of sleep quantity and quality. Actigraphy is a motion detector that is attached to the wrist or a belt (and to the ankle in the case of small infants). It records movement activity and with the appropriate algorithms can be used to evaluate whether a person is asleep or awake. The accuracy of actigraphy recordings has been assessed in comparison with polysomnography results; the results obtained from both methods have been shown to correspond well. Previous studies have demonstrated over 85 per cent correspondence between actigraphy and polysomnography (Jean-Louis, Kripke, Cole, Assmus, & Langer, 2001; Sadeh, Sharkey, & Carskadon, 1994).

1.1.6 Prevalence and consequences

Sleep problems appear to be rather common in young children, and various studies have reported susceptibility in 14-26 per cent of preschool-age children (Hiscock, Canterford, Ukoumunne, & Wake, 2007; Ottaviano et al., 1996; Smedje, Broman, & Hetta, 1998) and in from five to as high as 43 per cent of school-age children (Blader, Koplewicz, Abikoff, & Foley, 1997; Kahn et al., 1989; Meijer, Habekothe, & Van Den Wittenboer, 2000; Rona, Li, Gulliford, & Chinn, 1998; Smedje, Broman, & Hetta, 2001). The variation in results is largely attributable to the different data-collecting methods and the varying definitions of sleep problems. Even though their definition is still under debate, several studies have addressed the impact of sleep problems on children’s wellbeing. The most obvious outcome is daytime sleepiness (Saarenpää-Heikkilä, Laippala, & Koivikko, 2001). Recently, however, sleep disorders have also been linked to problems in child populations such as somatic illnesses (Bloom et al., 2002; Pirinen, Kolho, Simola, Ashorn, & Aronen, 2010), poor school achievement (Bruni et al., 2006; Gozal, 1998; Meijer et al., 2000; Paavonen et al., 2002), cognitive performance (Paavonen et al., 2010; Steenari et al., 2003), and emotional and behavioural problems (E. T. Aronen, Paavonen, Fjallberg, Soininen, & Torronen, 2000; Pesonen et al., 2010; Rosen et al., 2004). Furthermore, poor sleep quality or altered sleep may trigger or maintain the symptoms among adolescents with somatic or psychiatric disorders (Brand & Kirov, 2011), for review). The detrimental effects if sleep problems are not restricted to the children concerned, but may also negatively affect parental wellbeing. Among young children in particular, sleep problems are associated with poorer parental health (Martin, Hiscock, Hardy, Davey, & Wake, 2007).

Sleep problems are related to several emotional and psychophysiological difficulties, and are also rather persistent and may predict adverse outcomes in the future. It has been shown that 42 per cent of children who had sleeping difficulties at the age of eight months still had them at the age of three years (Zuckerman, Stevenson, & Bailey, 1987). Childhood sleep problems are also linked to later behavioural difficulties and substance abuse (Scher et al., 2005; Wong, Brower, Fitzgerald, & Zucker, 2004).

The relationship between sleep problems and emotional, behavioural and somatic symptoms tends to be complex and bidirectional. In other words, poor sleep can both exacerbate and be attributed to these problems (Shanahan, Copeland, Angold, Bondy, & Costello, 2014). However, there are some indications that in certain cases sleep problems may contribute to emotional and behavioural disturbances rather than vice versa, specifically with regard to symptoms of depression (Gregory, Rijsdijk, Lau, Dahl, & Eley, 2009; Lam, Hiscock, & Wake, 2003; Rosenström et al., 2012), aggression in children with obstructive sleep apnoea (Ali, Pitson, & Stradling, 1996; Pakyurek, Gutkovich, & Weintraub, 2002), and inattention in children with developmental disabilities (van Litsenburg, Waumans, van den Berg, & Gemke, 2010). Sleep disturbances among children with neurodevelopmental disorders, such as Asperger syndrome or conduct Disorder/oppositional Defiant Disorder may magnify their symptoms, which may then ease if sleeping could be improved (Aronen, Lampenius, Fontell, & Simola, 2013; Paavonen et al., 2003).

1.1.7 The association between sleep and both sensory and cognitive processing

Sleep affects cognition and brain functions underlying cognitive performance, influencing a number of processes such as reaction times, sorting, logical reasoning and memory (Goel, Basner, Rao, & Dinges, 2013). Studies using neuroimaging techniques indicate that several brain areas are affected. The effects are probably strongest on the prefrontal cortex (PFC), which influences both top-down and bottom-up processes (Boonstra, Stins, Daffertshofer, & Beek, 2007, for a review). Studies based on functional magnetic resonance imaging (fMRI) report that sleep restriction increases cerebral activity and activation in other areas of the brain (Drummond & Brown, 2001;

Drummond, Gillin, & Brown, 2001), which could reflect adaptive compensatory recruitment. There is also evidence that long-term sleep disturbances increase neural activation. For example, adults with obstructive sleep apnea syndrome (OSAS) were shown to have increased brain activation during verbal learning tasks (Ayalon, Ancoli-Israel, Klemfuss, Shalauta, & Drummond, 2006). However, long-term sleep disturbances may also be related to decreased cerebral activity (Ayalon et al., 2006; Ayalon, Ancoli-Israel, & Drummond, 2009; Thomas, Rosen, Stern, Weiss, & Kwong, 2005). For example, severe sleep problems can lead to diminished cerebral activation during response inhibition (Ayalon et al., 2009).

In addition, several ERP studies investigate the association between sleep and cerebral responses. It has been shown in a recent study that adults who have a tendency to sleep less than is sufficient (≤6h), show fewer attention-related cerebral responses than those who have enough sleep (Gumenyuk et al., 2011). However, Bortoletto et al. (2011) found increased cerebral responses after sleep restriction, which they suggested were related to enhanced cortical excitability to acoustic stimuli (Bortoletto, Tona Gde, Scozzari, Sarasso, & Stegagno, 2011). Furthermore, Salmi et al. (2005) found an association between an enhanced attention orientation and decreased sleep quality in healthy adults, which they interpreted as reflecting increased distractibility due to poor sleep.

With regards to the research reported in this thesis, ERPs were used to measure the effects of sleep on children's cognitive functions. Their high temporal accuracy enables the inspection of distinct cognitive processes and their timing.

1.2 Event-related potentials as a means of studying sensory processing

1.2.1 ERPs

Event-related potentials (ERPs) allow the non-invasive monitoring of monitor brain processes and their modulation. With a milliseconds time resolution they capture fast neural events and high-frequency oscillations, thereby facilitating the study of sensory and cognitive processes and their association with sleep (Banaschewski & Brandeis, 2007; Näätänen, 1992) ERPs are transient voltage changes in the EEG that are triggered by, and time-locked to, sensory, motor or cognitive events. They fall into three groups according to their latency and site of generation. Earliest are the brainstem auditory evoked potentials (BAEP) that occur at 0–10 ms after stimulus onset and are generated in the brainstem and subcortical structures (Legatt, Arezzo, & Vaughan, 1988). Middle-latency auditory evoked potentials (MLAEP) represent the initial activation of the auditory cortex and occur at ca. 10–50 ms after stimulus onset (Liegeois-Chauvel, Musolino, Badier, Marquis, & Chauvel, 1994). Long-latency auditory evoked potentials (LLAEP) have a peak latency of ca. 50 ms or more and are generated in the auditory cortex and related cortical areas.

LLAEPs are dominated by the P1 and N2 peaks in children, and by the P1-N1-P2-N2 complex in adults (see Figure 1) (Čeponienė, Rinne, & Näätänen, 2002). All BAEP and MLAEP components as well as P1, N1 and P2 of LLEAP components are exogenous. Exogenous components are obligatorily elicited by all stimuli, and mainly reflect their physical features, whereas endogenous LLAEP components (MMN, N2, P3a) reflect cognitive processes and are not obligatorily evoked by every stimulus (Näätänen, 1992). Although insufficiently studied, childhood P1 and N2 ERPs are considered to reflect similar cortical processes as those in adults (Čeponienė et al., 2002; Čeponienė, Alku, Westerfield, Torki, & Townsend, 2005). It was also suggested that these early developing P1 and N2 components reflect the neural processes critical for the development of basic auditory skills, sound recognition, and receptive language skills (Čeponienė, Torki, Alku, Koyama, & Townsend, 2008).

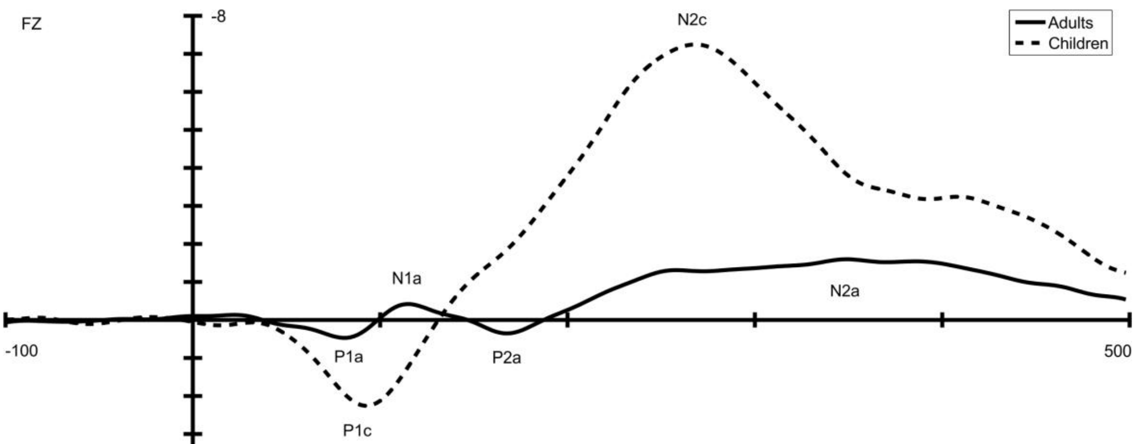

Figure 1. *An example of a Grand average waveforms of the auditory ERP for a standard sound from a group of adult participants (continuous line; adopted from Salmi et al., 2005) and from a group of child participants (dashed line; adopted from Simola et al., submitted (**Study IV**)).*

1.2.2 ERPs reflecting acoustic feature processing in children

P1 peaking at ca. 50 ms after stimulus onset primarily reflects the sensory encoding of auditory stimulus attributes. In children, P1 precedes components receiving contributions from endogenous processes such as N2. It is generated in the lateral part of Heshl’s gyrus, which lies at the secondary auditory cortex (Liegeois-Chauvel et al., 1994; Smith & Kraus, 1988). P1 is rather insensitive to sound features such as loudness and pitch and is persistently present even during sleep (Erwin & Buchwald, 1986; Paavilainen et al., 1987). The amplitude diminishes only with very fast (10 Hz) click rates, which reflects the fast refractory time of neurons involved in generating P1 (Erwin & Buchwald, 1986). Insensitivity to sound features, persistent presence during sleep, and fast refractory time indicate that P1 reflects early the pre-perceptual processing of acoustic sound features.

N2 amplitude has been shown to increase after the repetition of sounds, which is suggested to reflect the development of memory representations of sounds (Karhu et al., 1997), and amplitudes are larger for complex tones than for simple tones or vowels (Čeponienė et al., 2001). Furthermore, the N2 amplitude for phonetic sounds is larger than for their non-phonetic counterparts, which may be related to more advance sensory encoding such as phonological processing (Čeponienė et al., 2005). According to the results of several previous studies N2 is sensitive to the earliest aspects of phonological and semantic information encoded in words (Hagoort, 2008, for a review)

1.2.3 ERPs reflecting change detection and attention orientation

If there is a change in or a violation of regularity in a sound sequence, the mismatch negativity (MMN), an endogenous negative ERP, is elicited at 150–250 ms after the change. The main neural sources of MMN are in the auditory cortices, but there is also subcomponent at the frontal lobes (Kujala, Tervaniemi, & Schroger, 2007; Näätänen, Paavilainen, Rinne, & Alho, 2007). MMN reflects the accuracy of cortical sound discrimination and learning-related auditory neural plasticity (Kujala & Näätänen, 2010; Näätänen, Gaillard, & Mäntysalo, 1978; Näätänen et al., 2007). Large sound changes elicit strong MMN amplitudes, which become smaller when the acoustic change diminishes (Kujala, Kallio, Tervaniemi, & Näätänen, 2001). In adults, MMN overlaps with the N1 and P2 components, both elicited by standard and deviant stimuli. Therefore, the MMN is quantified from the difference waveform calculated by subtracting the ERP for the standard stimulus from that for the deviant (Alho et al., 1998).

Because robust MMNs can be obtained from infancy onwards, MMN is a feasible tool for examining cortical sound-discrimination functions across the lifespan (Kujala & Näätänen, 2010), and has been extensively used to investigate dysfunctions of neural processing in children with learning and language impairments. For example, atypical MMNs have been found in children with autism spectrum disorders (Kujala et al., 2010; Lepistö et al., 2005), dyslexia or the risk for dyslexia (Lachmann, Berti, Kujala, & Schroger, 2005; Lovio, Näätänen, & Kujala, 2010) and attention deficit (Huttunen-Scott, Kaartinen, Tolvanen, & Lyytinen, 2008). These results imply that small MMNs are associated with deficient sound-discrimination skills (Kujala et al., 2007, for a review). On the other hand, enhanced MMN amplitudes and shortened latencies have been identified in children with autism spectrum disorder for particular types of stimulus change for example, which was interpreted as indicative of hypersensitive sound processing (Kujala, Lepistö, & Näätänen, 2013).

It is not uncommon after an unexpected event for MMN to be followed by P3a, an endogenous positive LLAEP reflecting the orientation of attention toward a stimulus change (Polich, 2007). P3a peaks at approximately 200–400 ms after the change and is most easily detectable from the deviant-minus-standard difference waveform. There are two subcomponents, the first one being generated in the superior temporal plane of the auditory cortices (Alho et al., 1998; Escera, Alho, Winkler, & Näätänen, 1998), and the other in the prefrontal and parietal cortices (Yago, Escera, Alho, Giard, & Serra-Grabulosa, 2003). The hippocampus also contributes to P3a generation (Knight, 1996). Whereas the frontal subcomponent of MMN appears to be associated with preattentive attention switch initiation, P3a response seems to reflect the resulting attention switch (Escera, Alho, Schroger, & Winkler, 2000).

1.2.4 Previous sleep-related ERP studies among children

Whereas the effects of sleep and sleep disturbances on the neural basis of sensory processing have been investigated extensively in adults, thus far only a few studies focus on these issues in children. Two recent studies assessing the effects of OSAS and occasional snoring on children's ERPs, elicited by frequent and infrequent target stimuli in an oddball paradigm, reported effortful neural processing in the children under investigation (Barnes et al., 2009; Barnes, Gozal, & Molfese, 2012). Furthermore, an increased apnoea index (AI) in children who snore was significantly associated with enhanced N1 and P2 amplitudes (Key, Molfese, O'Brien, & Gozal, 2009). It was suggested that these results reflected enhanced engagement of resources for the detection of stimulus onsets, early orienting (N1) and perceptual analysis (P2) and possibly indicated on increased allocation of attention (Key et al., 2009).

However, even very brief sleep deprivation may modulate children’s neural processing; a sleep restriction of one hour a night for a week was found to diminish the amplitude of P3oo for target sounds (Molfese et al., 2013). The implication of these results is that sleep restriction markedly decreases neural processing during tasks involving high processing demands (Molfese et al., 2013).

2. Aims of the study

This thesis is about sleep problems among Finnish children aged between three and 11 years. The aim is to assess the prevalence and outcomes related to behavioural, emotional, and somatic symptoms as well as to auditory cognitive functions, from both a cross-sectional and a longitudinal perspective.

Study I focused on preschool-age children and their sleep. There were three goals: first, to determine the prevalence of the entire spectrum of parent-reported sleep problems and daytime sleepiness among Finnish children aged between three and six years; second, to evaluate the association between different sleep problems and daytime sleepiness; third, to provide validation and norms for the Sleep Difficulty Scale for Children (SDSC) in Finnish preschool-age children.

Study II followed up the children from preschool to elementary-school age (for four years). The aim was to determine the changes in frequency and phenotype of sleep problems during this period, and to investigate their persistence.

The aim in **Study III** was to enhance understanding of the effects of sleep problems on children´s behaviour and emotional wellbeing. The focus was on the predictive effects on behavioural, emotional, and somatic symptoms, problems that become evident a) only at 3-6 years of age and b) only at 7-11 years of age, and c) that persisted.

The purpose of **Study IV** was to determine the association between natural variation in sleep and auditory processing in the brain related to sound encoding (P1, N2), pre-attentive sound-change detection (MMN), and attention orientation (P3a) in school-age children.

3. Methods

3.1 Participants

Studies I-III were part of a larger epidemiological study on snoring among Finnish children. The larger study included a random sample of 2,100 children between the ages of one and six years, representing seven per cent of all children of that age group living in the Helsinki metropolitan area at the time of the sampling in 2005 (Liukkonen, Virkkula, Aronen, Kirjavainen, & Pitkäranta, 2008). The sample was randomly selected from the Population Register Centre, Helsinki. The questionnaires were mailed to parents periodically between January 2005 and September 2006. Of the preschool[2] (3-6 years old) children in the sample (n = 1,400), 904 families completed the questionnaires and were included in **Study I**. For the follow-up studies **(II & III)** the questionnaires were sent with two reminders (2009-2010) to the 904 families responding at the baseline (2005-2006). Valid responses were received from 481 families for **Study II**, and 470 families for **Study III**, which represented 53 and 52 per cent respectively, of the participants at baseline, and 34 per cent of the original sample of 1,400 children. The sample used in **Study IV** comprised eighteen healthy children with normal hearing and no history of sleep or neurological disorders or regular medication. Two of these children were excluded on the grounds of actigraphy malfunction, and one because of a poor signal-to-noise ratio in the EEG data. Thus, 15 children (aged 8-11 years, mean 9.2 years, 11 males) were included in the analysis.

3.2 The measures used in Studies I – III

3.2.1. Questionnaires

3.2.1.1 Background information

Information on socioeconomic status, the language spoken in the family, ethnicity, and family structure was given on a separate form (**Studies II-III**). Socioeconomic status was classified as follows: high (managers and higher-level white-collar workers),

[2] In this study, the term “preschool age” refers to children aged between three and six years of age, which is the age group in **Study I**. In Finland children starts school in the autumn of the year they reach the age of seven.

intermediate (entrepreneurs and low-level white-collar) and low (manual workers). The form also included questions on the child's long-term or permanent (physical or emotional) medical condition, and whether the child needed support at school (i.e. remedial instruction, support from a special-education teacher, or was in a remedial class).

3.2.1.2 Sleep problems

The parents completed the Finnish version of the "Sleep Disturbance Scale for Children" (SDSC) questionnaire both at baseline (**Study I)** and at follow-up (**Studies II & III).** The original SDCS developed by Bruni et al. (1996) was validated on a sample of 1,157 children (aged 6.5–15.3 years) from the general population. The questionnaire contains 26 questions, pertaining to the previous six months of the child's life. Responses are scored on a Likert-scale [1, never; 2, occasionally (1–2 times a month); 3, sometimes (1–2 times a week); 4, often (3–5 times a week); 5, always (daily)]. Then SDSC comprises a Total Sleep Problems scale and the following six subscales reflecting different types of common problems: (1) Disorders of Initiating and Maintaining Sleep, (2) Sleep Breathing Disorders, (3) Disorders of Arousal, (4) Sleep-Wake Transition Disorders, (5) Disorders of Excessive Somnolence, and (6) Sleep Hyperhidrosis (Bruni et al., 1996). For more details concerning the structure of the questionnaire, see Table 2. The SDSC was translated into Finnish under the supervision of one of the authors (E. A. in **Studies** I–III) but was not back-translated into English.

3.2.1.3 Psychosocial Symptoms

The parents completed the "Child Behavior Checklist" (CBCL), a standardised questionnaire evaluating psychosocial symptoms and somatic complaints in 6-18-year-old children as reported by their parents (**Study III)** (Achenbach & Rescorla, 2001). The checklist has been validated in 24 countries including Finland (Rescorla et al., 2007). The questionnaire comprises 113 items, scored on a Likert-scale (0, Not true; 1, somewhat or sometimes true; 2, very true or often true). The CBCL includes the Total Problem, Emotional (internalising) Problem and Behavioural (externalising) Problem broad-band syndrome scales and eight narrow-band scales: Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, Aggressive Behaviour, Rule-Breaking Behaviour, Thought Problems, Social Problems, and Attention/Hyperactivity. The broad-band Emotional (internalizing) problems scale includes Anxious/Depressed, Withdrawn/Depressed and Somatic Complaints narrow-band scales, and Behavioural (externalising) Problems scale includes the Aggressive Behaviour and Rule-Breaking Behaviour narrow-band syndrome scales (see Table 3).

The raw scores were standardised (T-scores) by means of ADM (version 6.5) scoring software. The CBCL gives subclinical/borderline (broad-band T-score of 60-63, narrow-band T-score of 65-69) and clinical (broad-band T-score >63, narrow-band T-score >69) ranges to describe the severity of the psychiatric difficulty.

Table 2. *Sum scales and single items of the* Sleep Disturbance Scale for Children (SDCS) *questionnaire*

Disorders of Initiating and Maintaining Sleep
I. How many hours of sleep does your child get on most nights
2. How long after going to bed does your child usually fall asleep
3. The child goes to bed reluctantly
4. The child has difficulty getting to sleep at night
5. The child feels anxious or afraid when falling asleep
10. The child wakes up more than twice per night
11. After waking up in the night, the child has difficulty to fall asleep again
Sleep Breathing Disorders
13. The child has difficulty breathing during the night
14. The child gasps for breath or is unable to breath during sleep
15. The child snores
Disorders of Arousal
17. You have observed the child sleepwalking
20. The child wakes from sleep screaming or confused so that you cannot seem to get through to him/her, but has no memory of these events the next morning
21. The child has nightmares which he/she doesn't remember the next day
Sleep-Wake Transition Disorders
6. The child startles or jerks parts of the body while falling asleep
7. The child shows repetitive actions such as rocking or head banging while falling asleep
8. The child experiences vivid dream-like scenes while falling asleep
12. The child has frequent twitching or jerking of legs while asleep or often changes position during the night or kicks the cover off the bed
18. You have observed the child talking in his/her sleep
19. The child grinds teeth during sleep
Disorders of Excessive Somnolence
22. The child is unusually difficult to wake up in the morning
23. The child awakes in the morning feeling tired
24. The child feels unable to move when waking up in the morning
25. The child experiences daytime somnolence
26. The child falls asleep suddenly in inappropriate situations
Sleep Hyperhidrosis
9. The child sweats excessively while falling asleep
16. The child sweats excessive during the night

Table 3. *Broad-band and sub-scales of the Child Behavior Checklist (CBCL), and the items included in these scales.*

Total Problems							
Emotional (internalising) Problems						Behavioural (externalising) Problems	
Anxious/ Depressed	Withdrawn/ Depressed	Somatic Complaints	Social Problems	Thought Problems	Attention/ Hyperactivity	Rule-Breaking Behaviour	Aggressive Behaviour
14. Cries a lot 29. Fears certain animals, situations, or places other than school 30. Fears going to school 31. Fears he/she might think or do something bad 32. Feels he/she has to be perfect 33. Feels or complains that no one loves him/her 35. Feels worthless or inferior 45. Nervous, highstrung, or tense 50. Too fearful or anxious 52. Feels too guilty 71. Self-conscious or easily embarrassed 91. Talks about killing self 112. Worries	5. There is very little he/she enjoys 42. Would rather be alone than with others 65. Refuses to talk 69. Secretive, keeps things to self 75. Too shy or timid 102. Lacks Energy 103. Unhappy, sad or depressed 111. Withdrawn, doesn't get involved with others	47. Nightmares 49. Constipated, doesn't move bowels 51. Feels dizzy or lightheaded 54. Overtired without good reason 56a. Aches, pains 56b. Headaches 56c. Nausea, feels sick 56d.Problems with eyes 56e. Rashes or other skin problems 56f. Stomachaches 56g. Vomiting, throwing up	11. Clings to adults or too dependent 12. Complains of loneliness 25. Doesn't get along with other kids 27. Easily jealous 34. Feels others are out to get him/her 36. Gets hurt a lot, accidents-prone 38. Gets teased alot 48. Not liked by other kids 62. Poorly coordinated or clumsy 64. Prefers being with younger kids 79. Speech problems	9. Can't get his/hers mind off certain thoughts; obsessions 18. Deliberately harms self or attempts suicide 40. Hears sounds or voices that aren't there 46. Nervous movements or twitching 58. Picks Nose, skin or other body parts 59. Plays with own sex parts in public 60. Plays with own sex parts too much 66. Repeats certain acts over and over; compulsions 70. Sees things that aren't there 76. Sleeps less than other kids 83. Stores up too many things he/she doesn't need 84. Strange behavior 85. Strange ideas 92. Talks or walks in sleep 100. Trouble sleeping	1. Acts too young for his/hers age 4. Fails to finish things he/she starts 8. Can't concentrate, can't pay attention for long 10. Can't sit still, restless, or hyperactive 13. Confused or seems to be in a fog 17. Daydreams of gets lost in his/hers thoughts 41. Impulsive or acts without thinking 61. Poor school work 78. Inattentive or easily distracted 80. Stares blankly	2. Dinks alcohol without parents approval 26. Doesn't seem to feel guilty after misbehaving 28. Breaks rules at home, school or elsewhere 39. Hangs around with others who gets in trouble 43. Lying or cheating 63. Prefers being with older kids 67. Runs away from home 72. Sets fires 73. Sexual problems 81. Steals at home 82. Steals outside home 90. Swearing or obscene language 96. Thinks about sex too much 99. Smokes, chews or sniffs tobacco 101. Truancy, skips school 105. Uses drugs for nonmedical purposes 106. Vandalism	3. Argues a lot 16. Cruelty, bullying, or meanness to others 19. Demands a lot of attention 20. Destroys his/hers own things 21. Destroys things belonging to his/hers family or others 22. Disobedient at home 23. Disobedient at school 37. Gets in many fights 57. Physically attacks people 68. Screams a lot 86. Stubborn, sullen or irritable 87. Sudden changes of mood or feelings 88. Sulks a lot 89. Suspicious 94. Teases a lot 95. Temper tantrums of hot temper 97. Threatens people 104. Unusually loud

3.2.2 Data analysis

Sleep disturbances occurring three or more times a week were considered to be a problem during preschool-age (**Study I**). This definition has been used in earlier studies involving preschool-age children (Smedje et al., 1998), and also recently in describing problematic sleep among school-age children (Romeo et al., 2013). Simple correlation and multiple regression analyses were conducted to determine the associations between different sleep difficulties and tiredness during the daytime. SDSC subscales reflecting sleep difficulties were entered as independent variables in the regression equation, and the Excessive Somnolence subscale as a dependent variable.

In **Study II** the changes in sleep-disturbance subscales from preschool age to school age were assessed by means of repeated-measures ANOVA. For the analysis, the children in the 2010 sample were divided into age groups of 7-9 years (48%) and 10-12 years (52%). The SDSC subscale measurements in 2005 and 2010 were treated as within-subject variables; age, gender and the highest socioeconomic status in the family were treated as between-subject variables. As suggested by Bruni and colleagues, the presence of a sleep disturbance was defined as a score above the 75th percentile of the total sleep-disturbance scale at preschool age (Bruni et al., 1996). In the case of severe sleep disturbances at the same age the stricter definition of a score above the 90th percentile was used. The cut-off points for the 75th and 90th percentiles of the total sleep-disturbance scale were 46 and 51, respectively (mean 41, range 27–77). The same cut-off points (46 and 51) were also used to describe the presence of a sleep disorder during school age. The 75th-percentile criterion was considered mild, and the 90th-percentile criterion severe sleep disturbance. The same definition was used in both **Study II and Study III**.

Chi-squared analysis was used in **Study III,** to evaluate the associations between sleep problems and family factors, child health and support needed at school, whereas logistic regression was used to predict psychosocial problems relative to child´s history of sleep problems. The reference category was ‘no sleep problems at preschool or school age’. Age, gender, socio-economic status and the presence of a long-term medical condition were treated as covariates in the analyses. Scores within or above the subclinical range of the CBCL scales were considered to indicate psychosocial difficulties on a level that was likely to affect everyday life. Subclinical cut-off points were therefore used to divide the children into two groups: those with 1) psychosocial problems within the normal variation, and 2) psychosocial problems in the subclinical/clinical range. The scale Thought Problems was excluded because of the multiple sleep-related items: *76. Sleeps less than most kids*, *92. Talks or walks in sleep, and 100. Trouble sleeping*.

3.3 The measures used in Study IV

3.3.1 Sleep diary

The parents kept a simple sleep diary in which they registered start and end times of the actigraphy recording, the times of monitor removal (e.g., while showering and during vigorous sporting activities), the time when the child went to bed to sleep (rather than to read a book, for example), and waking times.

3.3.2 Objective estimation of sleep quality and quantity

Wrist worn actigraphys (Basic Motionlogger, Ambulatory Monitoring Inc New York) were used to record motor activity and objective sleep measurements **in Study IV**. Motor activity was recorded for three consecutive days (72 hours) in one-minute epochs and in natural surroundings (at home, at school, while engaged in hobbies). The recordings were on weekdays in order to avoid the confounding shifts in activity patterns often observed during weekends (Figure 2). The AW2 program (Ambulatory Monitoring Inc. New York) was used to translate motor-activity data and information of monitor removal as well as bedtimes and waking times into sleep variables. The algorithm developed by Sadeh and colleagues as follows: PS = 7.601 - 0.065*MW5 - 1.08*NAT - 0.056*SD6 - 0.073*ln(ACT),where MW5 is the average number of activity counts during a scored epoch and the window of five epochs preceding and following it; SD6 is the standard deviation of the activity counts during the scored epoch and the five epochs preceding it; NAT is the number of epochs with a activity level equal to or higher than 50 but lower than 100 activity counts in a window of 11 minutes including the scored epochs and the five epochs preceding and following it; and ln(ACT) is the natural logarithm of the number of activity counts during the scored epoch +1. If PS is zero or above, then the epoch is scored as sleep (Sadeh et al., 1994). Activity variables were obtained as follows: Sleep Minutes (= total minutes scored as sleep), Sleep Percentage [100× (Sleep Minutes + light sleep minutes)/ from the first sleep period until awakening)], Sleep Efficiency [100×(sleep minutes)/minutes of start-to-end night period] and Sleep Onset Latency (the first 20-min period consisting of at least 19 minutes of sleep). Sleep Percentage was differentiated from Sleep Efficiency by including Sleep latency, and not including light sleep.

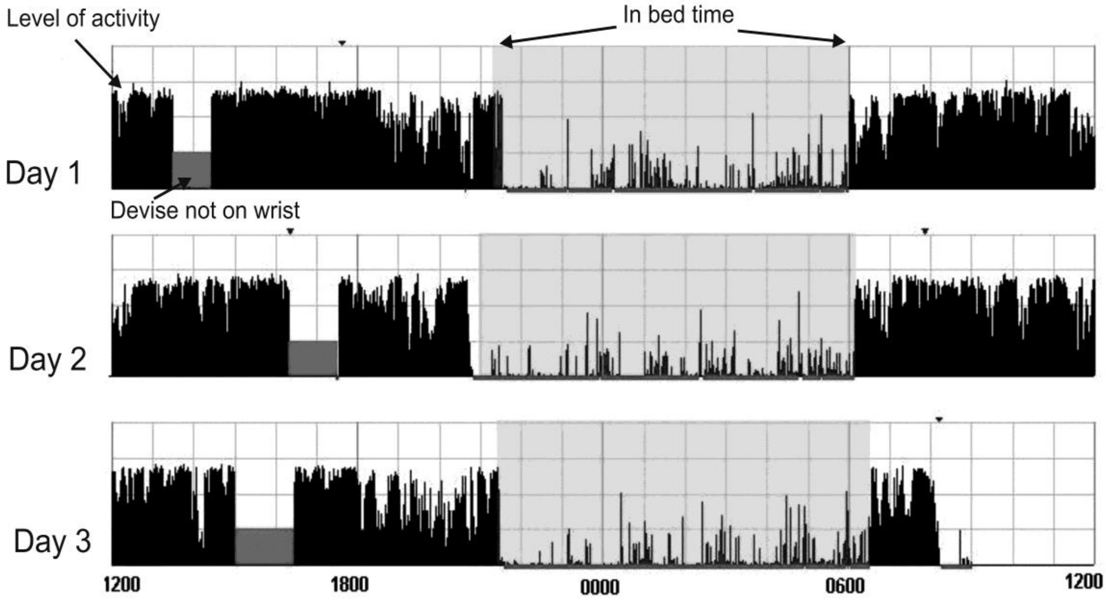

Figure 2. *An example of actigraphy activity data from one participant: The shaded area indicates the time period when the child was in bed according to the sleep diary kept by the parents*

3.3.3 Stimuli

A frequent harmonically rich tone (fundamental frequency of 230 Hz, harmonic partials of 460 and 690 Hz) with a duration of 105 ms served as the standard tone in the EEG recording of **Study IV**. It was occasionally replaced with deviant tones of infrequent (in five per cent of the cases for each deviant) frequency (fundamental frequency of 300 Hz, with partials of 600 and 900 Hz) and duration (length 190 ms) (Figure 3). During the experiment the children sat in a comfortable chair in an electrically shielded and sound-dampened room. The stimuli were presented through headphones with a constant stimulus-onset asynchrony of 700 ms while the children watched a self-selected, subtitled film without sound, and they were instructed to ignore the stimuli.

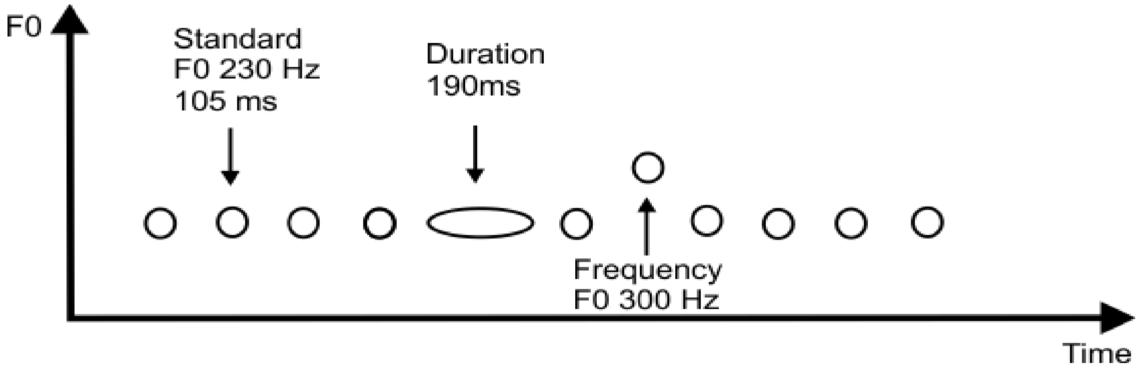

Figure 3. *A schematic illustration showing stimulus presentation in an oddball paradigm used in* ***Study IV***

3.3.4 Data acquisition and analysis

The EEG data used in **Study IV** was recorded using Neuroscan system with Ag/AgCl electrodes attached to Fz, F3, F4, Cz, C3, C4, T3, T4, Pz, PT3, PT4, LM (left mastoid), and RM (right mastoid) and referenced to the tip of the nose. The recording sites were based on the 10–20 system. Vertical and horizontal eye movements were monitored, with electrodes placed below and at the outer corner of the right eye. The EEG was continuously sampled at 250 Hz with an analog band-pass filter of 1–30 Hz. The epochs were 600 ms in length, including a 100 ms pre-stimulus baseline, and were separately averaged for the standard and deviant tones. Trials exceeding +-75 μV as well as trials for the standard tone following a deviant tone were rejected. The P1 and N2 responses were quantified from standard tone responses. The MMN and P3a responses were quantified from the differences in waveforms by subtracting the standard-tone ERPs from the deviant-tone ERPs. P1, N2, MMN, and P3a were identified at Fz. The individual mean amplitudes were determined as an average in a 50 ms window centred on the peak latencies determined from the group average. The windows for the latency identification were at 50-250 ms (P1), 100–400 ms (MMN and N2), and 200–500 ms (P3a) from stimulus onset at Fz.

A two-tailed t-test was conducted to determine whether the responses differed significantly from zero at Fz and Cz. Frontal (F3, Fz, F4), central (C3, Cz, C4), and parietal (PT3, Pz, PT4) composite variables were formed by averaging the amplitudes recorded from these electrodes in order to reduce the number of variables. Regression analyses were conducted to study the association of sleep quality with the composite ERP variables and latencies.

4. Results

4.1 Sleep problems at preschool-age

In **Study I** almost all the parents (99.1%) reported that their preschool-age children usually slept for at least nine hours. According to the responses to the single SDSC items, several types of sleep problems occurred between three and five times per week. The most frequently mentioned problems were Bed resistance (14.4%) and Difficulties in falling asleep (10.2%). Other typical problems included parasomnias such as Bruxism (10.2%), Sleep talking (6.4%), and Sleep terrors (2.1%). Sweating excessively while falling asleep (11.2%) and during sleep (12.9%) were also reported frequently (see Table 4).

All the sleep-problem scales correlated significantly with Disorders of Excessive Somnolence at preschool-age (r´s = 0.24 – 0.49, all $p < 0.001$). However, in the regression analysis the score on the Problems Initiating and Maintaining Sleep scale ($t = 12.85$, $p < 0.001$) was the strongest predictor of Disorders of Excessive Somnolence scores, and all the scale scores except for Sleep-Wake Transition Disorder predicted Disorders of Excessive Somnolence ($t = 2.56 – 12.85$, $p < 0.05 – 0.001$).

4.1.1 Validation of the sleep disturbance scale for children

An analysis of the internal consistency of the Total Problem Scale and subscales was conducted in order to validate the SDSC for use among Finnish preschool-age children, **(Study I)**. Good internal consistency was found for the Total problem scale and subscales: Disorders of Initiating and Maintaining Sleep, Disorders of Sleep-Related Breathing and Excessive Somnolence. Disorders of Arousal, Disorders of Sleep–Wake Transition, and Sleep Hyperhidrosis, on the other hand, showed only modest internal consistency. Table 5 gives the mean values, standard deviations and Cronbach’s alphas for each scale.

The Total score is the sum of the 26 items retained with a possible range from 26 to 130: it ranged from 27 to 85 and had a left-skewed distribution (Shapiro-Wilk $W = 0.93$, $p < 0.001$).

__Table 4.__ Frequencies (%) of sleeping problems among 3–6-year-old children (__Study I__.

	9 – 11	8 – 9	7 – 8	5 -7	less
1. How many hours of sleep does your child get on most nights	99.1	0.9	0.0	0.0	0.0
	<15	15 – 30	30 – 45	45 – 60	more
2. How long after going to bed your child usually fall asleep (minutes)	34.5	37.8	21.8	2.2	3.7
	Never	Occa-sionally	Some-times	Often	Always
3. The child goes to bed reluctantly	16.2	44.4	25.4	12.2	1.9
4. The child has difficulty getting to sleep at night	16.2	51.3	22.2	8.7	1.5
5. The child feels anxious or afraid when falling asleep	48.3	41.4	7.9	2.1	0.3
6. The child startles or jerks parts of the body while falling asleep	52.9	34.7	8.2	3.9	0.3
7. The child shows repetitive actions such as rocking or head banging while falling asleep	94	2.7	1.5	1.3	0.4
8. The child experiences vivid dream-like scene while falling asleep	87.5	9.8	2.2	0.4	0
9. The child sweats excessively while falling asleep	57.2	22.6	8.8	8.3	3.1
10. The child wakes up more than twice per night	58.8	32.7	6.6	1.2	0.6
11. After waking up in the night, child has difficulty to fall asleep again	69.4	26.8	2.5	0.9	0.4
12. The child has frequent twitching or jerking of legs while asleep or often changes position during the night or kicks the cover of the bed	69.8	23.3	4.4	1.9	0.6
13. The child has difficulty breathing during the night	82.1	14	3.4	0.2	0.2
14. The child gasps for breath or is unable to breath during sleep	81.7	14.3	3.0	0.7	0.3
15. The child snores	38.9	41.5	12.8	5.1	1.7
16. The child sweats excessive during the night	42.5	33.8	10.8	10	2.9
17. You have observed the child sleepwalking	89.5	8.0	2.1	0.4	0.0
18. You have observed the child talking in his/her sleep	22.8	55.1	15.7	5.4	1.0
19. The child grinds teeth during sleep	59.4	22.2	8.2	7.3	2.9
20. The child wakes from sleep screaming of confused so that you cannot seem to get through to him/her, but has no memory of these events the next morning	71.8	22.2	3.9	1.9	0.2
21. The child has nightmares which he/she doesn't remember the next day	49.8	43.3	6.3	0.6	0.1
22. The child is unusually difficult to wake up in the morning	43.4	40.5	10.5	4.8	0.9
23. The child awakes in the morning feeling tired	17.6	57.3	18.4	6.0	0.8
24. The child feels unable to move when waking up in the morning	90.4	6.7	2.5	0.3	0.0
25. The child experiences daytime somnolence	26.1	59.1	12.1	2.4	0.3
26. The child falls asleep suddenly in inappropriate situations	93.4	5.3	1.0	0.2	0.1

Table 5. *Descriptive statistics for the Sleep Disturbance Scale for Children (SDSC), total and subscales (n=904)*

SDSC Scales	Mean	SD	Cronbach's alpha
Total Sleep Problem Scale	41.6	8.3	0.8
Disorders of Initiating and Maintaining Sleep	12.2	3.1	0.7
Sleep Breathing Disorders	4.4	1.6	0.7
Disorders of Arousal	4.1	1.2	0.4
Sleep-Wake Transition Disorder	9.1	2.5	0.5
Sleep Hyperhidrosis	3.7	2.0	0.6
Disorders of Excessive Somnolence	8.1	2.1	0.8

4.2 The effects of age on sleep problems

Between-group comparisons on individual SDSC items (**Study I)** indicated that older children (5–6 years) were more reluctant to go to bed than younger ones (3–4 years) (chi-square 20.0; d.f. 4; P < 0.001). Feeling anxious or afraid when falling asleep (chi-square 13.8; d.f. 4; P < 0.01), bruxism (chi-square 14.5; d.f. 4; P < 0.01) and nightmares (chi-square 34.5; d.f. 4; P < 0.001) were also more common in the older children. Waking up more than twice a night (chi-square 16.0; d.f. 4; P < 0.01), confusional arousals (chi-square 28.8; d.f. 4; P < 0.001), startling or jerking movements of the body while falling asleep (chi-square 9.5; d.f. 4; P < 0.05), sweating excessively while falling asleep (chi-square 12.3; d.f. 4; P < 0.05), and night sweating (chi-square 17.3; d.f. 4; P < 0.01) were more common among the younger children, however age differences occurred in only one of the SDSC subscales: hyperhidrosis which more common in the younger children (t = 4.1; d.f. = 902; P < 0.001).

Most sleep problems diminished after the transition from preschool to schoolage (**Study II**). A significant within subject decrease was observed in the following: the child shows repetitive actions such as rocking or head banging while falling asleep (p < 0.05); the child sweats excessively while falling asleep (p < 0.01) the child sweats excessively during the night (p < 0.001); and the child grinds his/her teeth while asleep (p < 0.01). No significant increase was observed in any of the sleep problems under investigation. There were also a decline in the subscale scores from preschool to school age, which was in the following subscales: Disorders of Initiating and Maintaining Sleep ($F_{1,452}$ = 13.7, p < 0.001), Sleep-Wake Transition Disorders ($F_{1,452}$, 4.1, p < 0.05), Sleep Hyperhidrosis ($F_{1,452}$ = 6.5, p < 0.05) and Disorders of Excessive Somnolence

($_{F1,452}$ = 10.2, $p < 0.01$) (see Table 6 for details of the SDSC scales).

Table 6. *Descriptive statistics for the SDSC total and sleep-problem subscales, children at the age of three to six and seven to eleven (Study II, n. 481)*

				Percentiles	
		Mean	SD	75th	90th
2005 (3-6 y.)	Total Sleep Problem Scale	41.3	7.7	46.0	51.0
	Disorders of Initiating and Maintaining Sleep	12.0	2.9	14.0	16.0
	Sleep Breathing Disorders	4.2	1.5	5.0	6.0
	Disorders of Arousal	4.1	1.3	5.0	6.0
	Sleep-Wake Transition Disorder	9.1	2.5	10.0	12.0
	Disorders of Excessive Somnolence	8.1	2.0	9.0	11.0
	Sleep Hyperhidrosis	3.7	1.9	5.0	6.0
2010 (7-11 y.)	Total Sleep Problem Scale	38.4	7.3	41.0	48.0
	Disorders of Initiating and Maintaining Sleep	11.2	2.9	12.0	15.0
	Sleep Breathing Disorders	4.0	1.4	4.0	6.0
	Disorders of Arousal	3.9	1.3	4.0	5.0
	Sleep-Wake Transition Disorder	8.5	2.3	10.0	11.0
	Disorders of Excessive Somnolence	7.7	2.0	8.0	10.0
	Sleep Hyperhidrosis	3.0	1.5	4.0	5.0

4.3 The persistence of sleep problems from preschool to school age

During the four-year follow-up period (**Study II**), the majority of the children (70%) had no sleep problems (scoring above 46 points on the SDSC total-sleep-problem scale) in either study phase. Thirty five per cent of those, who had experienced at least mild sleep disturbances (scoring above the 75th percentile) at preschool age, still had sleep disturbances at school age (Figure 4): this equates to nine per cent of the children at the population level. Among those with severe forms (scores above the 90th percentile) of sleep disturbance at preschool age, 27 per cent of the children were reported to continue to experience severe sleep disturbances at school-age, equating to three per cent on the population level. Seven per cent of the children with no sleep problems at preschool age had experienced problems at school age, which were severe for two per cent of these children. On the population level these figures represent five and two per cent of school-age children, respectively.

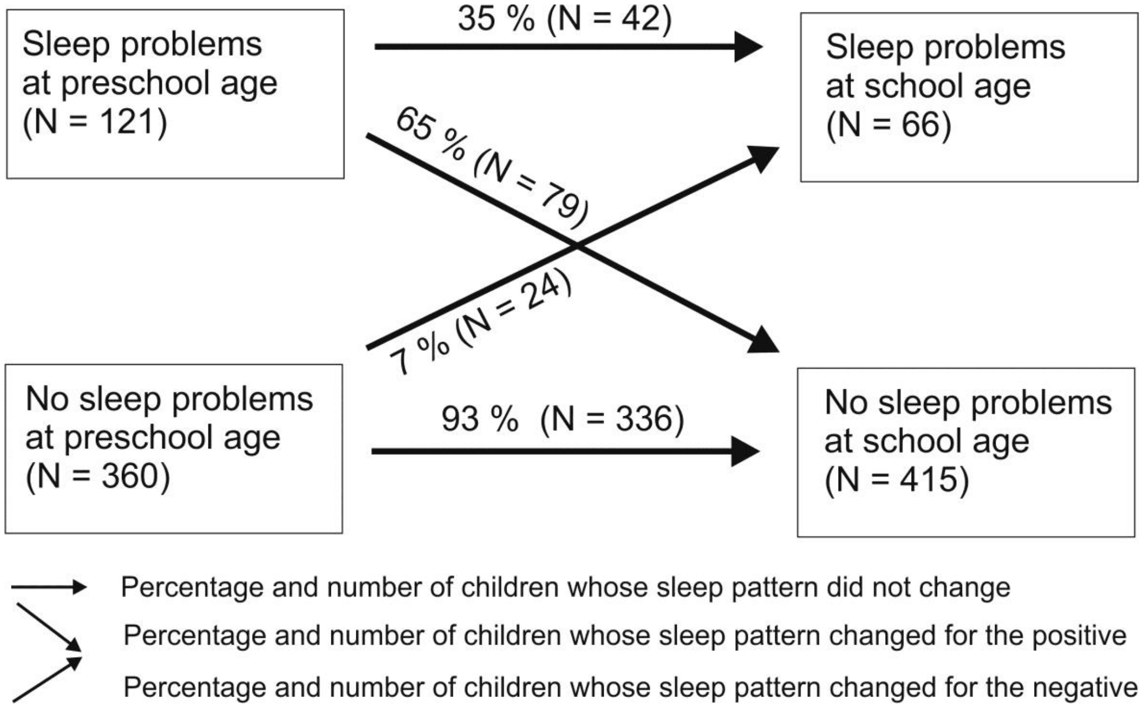

Figure 4. *The occurrence and course of sleep problems from preschool to school age, using 46 points on the SDSC Total Sleep Problem Scale as a the cut-off point their occurrence (scoring above the 75th percentile at preschool age).*

Children with persistent sleep problems had a 16-fold risk of scoring in the subclinical/clinical range on the Total Problem scale of the CBCL compared with children without such problems at either preschool or school age (**Study III**). All types of psychosocial symptoms studied, with the exception of withdrawn/Depressed symptoms, were strongly related to persistent sleep problems (Table 7).

Table 7. *The odds ratios for psychosocial symptoms rated in the subclinical/clinical range (Child Behavior Checklist, CBCL) at the age of 7-11 by the history of sleep problem*

CBCL scale	The occurrence of the sleep problem	Odds ratio (95% Ci)
	Sleep problems only at preschool-age	2.2 (1.0 – 4.6)*
CBCL Total Problems	Sleep problems only at school-age	5.7 (2.2 – 15.0)***
	Persistent sleep problems	15.6 (6.9 – 34.7)***
	Sleep problems only at preschool-age	1.5 (0.8 – 2.7)
Internalizing Problems	Sleep problems only at school-age	3.3 (1.4 – 8.0)**
	Persistent sleep problems	5.8 (2.8 – 12.1)***
	Sleep problems only at preschool-age	4.7 (1.4 – 15.3)*
Anxious/Depressed	Sleep problems only at school-age	2.6 (0.3 – 22.4)
	Persistent sleep problems	12.5 (3.8 – 40.5)***
	Sleep problems only at preschool-age	ns.
Withdrawn/Depressed	Sleep problems only at school-age	ns.
	Persistent sleep problems	ns.
	Sleep problems only at preschool-age	1.2 (0.6-2.8)
Somatic Complaints	Sleep problems only at school-age	4.1 (1.5 – 11.3)**
	Persistent sleep problems	7.3 (3.3 – 16.0)***
	Sleep problems only at preschool-age	1.4 (0.6 – 2.9)
	Sleep problems only at preschool-age	2.7 (0.9 – 8.2)
Social Problems	Sleep problems only at school-age	1.7 (0.3 – 9.5)
	Persistent sleep problems	10.6 (3.7 – 30.5)***
	Sleep problems only at preschool-age	2.0 (0.7 – 6.0)
Attention/Hyperactivity	Sleep problems only at school-age	6.8 (2.0 – 23.6)**
	Persistent sleep problems	12.8 (4.6 – 35.2)***
Externalizing Problems	Sleep problems only at school-age	2.8 (1.0 – 7.6)*
	Persistent sleep problems	7.1 (3.2 – 15.4)***
	Sleep problems only at preschool-age	2.0 (0.6 – 6.9)
Rule-Breaking Behavior	Sleep problems only at school-age	1.4 (0.2 – 12.4)
	Persistent sleep problems	7.0 (2.1 – 22.7)***
	Sleep problems only at preschool-age	1.9 (0.7 – 4.8)
Aggressive Behavior	Sleep problems only at school-age	2.1 (0.6 – 8.3)
	Persistent sleep problems	10.7 (4.5 – 25.7)***

*The reference category is no sleep problems (*p<0.05. **p<0.01. ***p<0.001).*

4.4 Neural correlates of sleep quality at school-age

According to the sleep diaries kept by parents, children were in bed for 9.9 hours on the average. The average sleeping time according to the actigraphy recordings was 8.8 hours per night with Sleep Efficiency above 80 per cent for all participants (see Table 8 for the descriptive statistics).

Table 8. *Descriptive statistics for the actigraphy sleep variables*

	Mean	Minimum	Maximum	SD
Sleep Minutes	518.7	431.0	632.7	60.0
Sleep Percentage	86.9	78.8	93.7	4.9
Sleep Efficiency	91.3	82.0	97.2	4.1
Sleep Onset Latency	17.4	5.7	36.3	9.2

The standard and deviant stimuli elicited a P1-N2 deflection, and the deviant stimuli elicited an MMN followed by a P3a (Figure 5). The peak amplitudes of P1 and N2 for all deviant and standard stimuli, as well as MMN and P3a for deviant stimuli significantly differed from zero at Fz ($p < 0.05$–0.001). Age significantly correlated with the N2 mean amplitude and was therefore treated as a confounding variable in the regression analyses. No association was found between gender and any of the sleep or ERP variables.

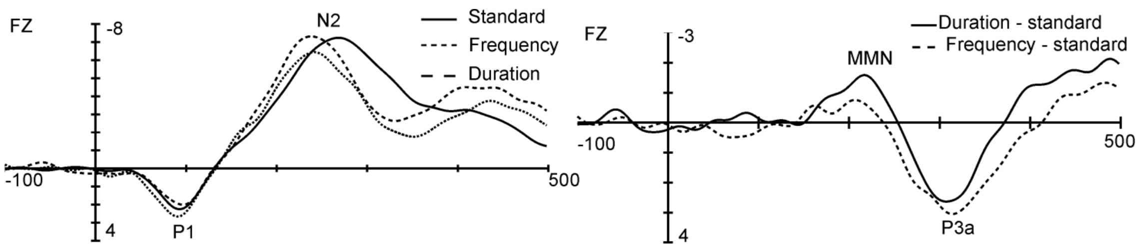

Figure 5. *Grand average waveforms of the ERP responses elicited by the standard tone and deviant tones (left), and deviant-minus-standard subtraction waveforms for the duration and frequency deviant tones (right)*

In the case of ERPs elicited by standard tones, associations between the N2 mean amplitudes and the sleep variables were observed at the frontal and central scalp areas. Furthermore, the amplitudes of the N2 and MMN elicited by a change in sound duration were associated with sleep variables at the frontal and central scalp areas and, N2 and P3a elicited by a sound-frequency change were associated with variables at frontal scalp areas. However, even though P3a was significantly associated with sleep in the regression equation, the whole model was not significant (p = 0.062). Table 9 gives regression coefficients. Enhanced (more negative) N2 for the standard tone and the duration change were associated with a shorter sleep time (in minutes) and the N2 for the frequency change was associated with decreased sleep quality (Sleep Efficiency). Enhanced (more negative) MMN for the duration change was associated with a decreased sleep quality (Sleep Percentage) and a prolonged time taken to fall asleep (Sleep Onset Latency). No association was found between the ERP latencies and the sleep variables.

Table 9. *Hierarchical regression for ERPs as measured by sleep variables (only significant associations are presented)*

Independent variable ERP		Dependent variable (Sleep)	R^2	ΔR^2	B	SE	Beta	t
Standard	Frontal N2	Sleep minutes	0.69	0.64	0.02	0.01	0.56	3.48**
	Central N2	Sleep minutes	0.65	0.59	0.03	0.01	0.53	3.07**
Frequency	Frontal N2	Sleep Efficiency	0.61	0.55	0.43	0.15	0.53	2.81*
Duration	Frontal N2	Sleep minutes	0.69	0.64	0.03	0.01	0.72	4.46***
	Central N2	Sleep minutes	0.76	0.72	0.03	0.01	0.65	4.56***
	Frontal MMN	Sleep Percentage	0.65	0.56	0.24	0.06	0.77	4.09**
	Frontal MMN	Sleep Onset Latency	0.65	0.56	-0.07	0.03	-0.44	-2.36*
	Central MMN	Sleep Percentage	0.40	0.31	0.20	0.07	0.65	2.77*

*The values reported are R^2, adjusted R^2 (ΔR^2), unstandardized coefficients (B), standard error of B (SE), standardized regression coefficients (Beta) and t-values with significance. The age of the children was controlled in an initial step. (*P < 0.05; **P < 0.01; ***P<0.001)*

5. Discussion

The results of the four studies reported in this thesis are consistent with findings from previous research indicating that sleep problems are common in young children. Although the problems were found to ease during maturation, there were indications that this does not apply to all children, as is commonly assumed. Some children were found to suffer from persistent sleep problems, which have severe consequences and are associated with far more adverse effects than short-term ones. It also appears from the findings that even modest disturbances in sleep quality may influence the processing of sensory information and could cause increased distractibility.

5.1 The presence of sleep problems

5.1.1 From preschool to school age

Unlike many earlier studies (Ali, Pitson, & Stradling, 1994; Hiscock et al., 2007; Lavigne et al., 1999; Shang et al., 2006; Smedje et al., 1998), **Studies I-III** covered a broad range of sleep related, resulting in a sleep-problem-prevalence rate as high as 45 per cent among preschool age children (**Study I**) and 31 per cent for school age children (**Study II**). Although these frequencies are high, it should be borne in mind that the figures include many kinds of problems covered in SDSC questionnaire, not all of which have the same impact on children's wellbeing and daily alertness. As noted in **Study I**, different problems had different impacts on daytime activity. Problems related to initiating and maintaining sleep, breathing issues and Disorders of Arousal had more adverse effects than those related to nightly movements in sleep.

Problems related to the initiation of sleep were rather common among the preschool-age children. The most commonly reported problem was bedtime resistance; according to the parents, 14.1 per cent of preschool-age children in the sample were often reluctantly going to bed. This is about the same prevalence rate as reported among Swedish five-to-six-year-olds (12.6%) and slightly higher than among Italian children of the same age (9.2%) (Romeo et al., 2013; Smedje et al., 1998). Difficulties falling asleep at night were also common (10.2%), the prevalence being comparable to that reported with regard to Swedish (9.2%) and Australian (12.8%) preschool-age children, but clearly higher than among Italian preschoolers (3.7%) (Hiscock et al., 2007; Romeo et al., 2013; Smedje et al., 1998). Bruxism (10.2%) and sleep talking (6.4%) appear to be common parasomnias in Finnish children, the prevalence rates being slightly higher than those found in Swedish (4.6% and 3.0%, respectively) and Italian (6.7% and 3.5% respectively) studies (Romeo et al., 2013; Smedje et al., 1998). Other common problems included sweating while falling asleep (11.2%) and while sleeping (12.9%) and body movements while falling asleep (4.2%). The high frequency of sweating seems to be unique in Finnish children; in that no other study reported night-time sweating to be this common. An Italian study reported sweating at falling asleep and during the night among 6.8 per cent and 7.2 per cent of the study sample, respectively (Romeo et al., 2013). Although in some cases nocturnal sweating may be related to other sleep-related problems such as sleep related breathing issues, only one third of the children who were reported to sweat excessively when falling asleep and while sleeping (36% and34 %, respectively) snored in their sleep. It is more likely that frequencies of this magnitude are at least partly related to the Finnish climate (warm summers and cold winters sometimes overcompensated with excessive clothing and heating) and house-construction standards in that insulation that protects against the cold in winter may cause heat retention in the summer.

One commonly cited sleep problem in preschool-age children is waking up during the nights which nevertheless affected a surprisingly low proportion of these Finnish children, only 1.8 per cent: previous studies have reported prevalence between 13 and 18 per cent (Hiscock et al., 2007; Ottaviano et al., 1996; Romeo et al., 2013; Smedje et al., 1998). The low prevalence found in this study could be partly attributable to the strict definition of the problem: waking up more than twice a night at least three times a week. Occasional night waking (1–2 times a week) was reported in 6.6 per cent of the children. Many earlier studies on preschool-age children define night-time waking more broadly, which probably explains the discrepant results (Hiscock et al., 2007; Ottaviano et al., 1996; Smedje et al., 1998). However, an Italian study using the same criteria as we used in **Study I** reported an incident of night-time waking of 5.4 per cent, which is lower than reported in other studies but still clearly higher than in our sample of Finnish children (Romeo et al., 2013). These differences are probably linked to climate and light/dark cycles, as well as social-cultural factors: in fact, cross-cultural studies on sleep in young children have highlighted the importance of demographic and cultural variables in determining sleep patterns (Mindell, Sadeh, Kohyama, & How, 2010;

Sadeh, Mindell, & Rivera, 2011). Not only are there differences attributable to geographic diversity, there are also seasonal differences in the amount of daylight that affect children's activity and sleep patterns, especially at the latitude of which Finland is positioned (E. T. Aronen, Fjallberg, Paavonen, & Soininen, 2002).

Almost all specific sleep problems seemed to diminish slightly during the four-year follow-up period. However, a significant decrease was observed only in hyperhidrosis (sweating) and two sleep–wake transition disorders, namely repetitive actions such as head banging while falling asleep, and bruxism. Problems related to the initiation of sleep were rather common during both preschool and school age. The most commonly reported problem at school age was bedtime resistance, which has been found in some, but not all, previous studies to decrease from preschool to school age (Archbold et al., 2002; Iglowstein, Latal Hajnal, Molinari, Largo, & Jenni, 2006; Jenni & LeBourgeois, 2006; van Litsenburg et al., 2010).

Bedtime resistance seemed to decrease, although not statistically significantly, in our sample. Problems in falling asleep were also common, and decreased slightly during the follow-up. This result does not confirm findings in earlier studies indicating that sleep-onset difficulties increase with age (Jenni, Fuhrer, Iglowstein, Molinari, & Largo, 2005; van Litsenburg et al., 2010). Furthermore, sleep problems related to breathing and parasomnias seemed to be common in that parents reported rather frequent snoring, sleep talking and bruxism in both preschool and school-age children. The decrease in the incidence of bruxism confirms the results obtained in previous cross-sectional studies (Archbold et al., 2002; Liu et al., 2005; Shur-Fen Gau, 2006). Some children slept insufficiently: parents reported it to be rather common for their school-age children to have difficulty waking up, and to feel tired and stiff. Sweating was also rather common in both preschool and school-age children but decreased with age. Sweating (hyperhidrosis) is rarely cited as a sleep problem, and we found no previous studies on changes in incidence during childhood. However, a similar prevalence has been reported among school-age children (Spruyt, O'Brien, Cluydts, Verleye, & Ferri, 2005).

5.1.2 The persistence of sleep problems

One third of the children who had sleep problems at preschool age still had them at school-age, which means that they persisted thorough the four-year period. The children started school during this period, which in turn increased demands in terms of cognitive performance and social skills. This result is in line with previous findings among toddlers, in whom sleep problems at the age of eight months predicted problems at the age of three (Zuckerman et al., 1987). However, we found only one other population-based study reporting the natural history of sleep problems during the two-year period spanning school entry (Quach, Hiscock, Canterford, & Wake, 2009). However, the parents concerned were only asked whether or not children had sleep problems, and the children were grouped accordingly: having no sleep problems at either baseline or follow-up, having problems only at baseline, having problems only at follow-up, and having persistent sleep problem. The incidence of persistent sleeps problem was lower (2.9%) than in the present study (9%), although among adolescents insomnia problems over a one-year-course were even higher (14 %) (Roberts, Roberts, & Chan, 2008). However, we used a standardised sleep questionnaire covering a wide range of sleep problems, thereby increasing the sensitivity to their presence, as opposite to the single question used by Quach et al. (2009). Moreover, even though the higher prevalence among adolescents (Roberts et al., 2008) than reported in our study may be related to the differences in age groups, the wider timeframe (four years instead of one) we used could also explain the discrepancies. Finally, focusing on a specific sleep disorder, in this case OSAS, 54 per cent of the children previously diagnosed with the disorder still snored after the four-year follow-up period (Vlahandonis, Nixon, Davey, Walter, & Horne, 2013). In sum, it could be concluded from the findings of **Study II** and previous studies that sleep problems persist through childhood.

In **Studies II and III**) we used the same criteria (scoring ≥ 46 points) for both preschool and school-age children to describe the presence of sleep problems. Changing the age criteria for the school-age children to cover the upper quartile of the group increased level of persistence even more. When the upper quartile of the SDSC total score (46 and 42 for preschool and school aged children, respectively) was considered an indicator of sleep problems, 51 per cent of these children suffered from a persistent problem from preschool age onwards, and in only 49 per cent were the problems resolved. This result is in line with previous findings concerning children aged between nine to twelve years studied over one-year period (Fricke-Oerkermann et al., 2007). Moreover, of the children with no sleep problems at preschool age, only 14 per cent developed them at school age.

5.2 Adverse outcomes of sleep problems

5.2.1 Short-term problems

Ongoing sleep problems even without a history of disturbances (short term) are related to attention deficiency (**Study III**). Previous cross-sectional studies have also reported an association between attention deficiencies and sleep problems although, many of them have also imply that sleep problems are related to a much wider range of emotional and behavioural problems (E. T. Aronen et al., 2009; Chervin, Dillon, Archbold, & Ruzicka, 2003; Gregory et al., 2009; Hvolby, Jorgensen, & Bilenberg, 2009; O'Callaghan et al., 2010; Owens, Maxim, Nobile, McGuinn, & Msall, 2000; Paavonen et al., 2010; Pesonen et al., 2010). We found that current sleep problems were related only to attention deficiencies and somatic complaints. However, in the case of somatic complaints in the CBCL, interpretations should be made with caution because the subscale includes sleep related questions (*47. Nightmares*, and *54. Overtired without good reason)*, which tend to increase the interaction between the Somatic Complaints subscale of CBCL and the Total problem Scale of the SDSC, which include similar questions (Achenbach & Rescorla, 2001; Bruni et al., 1996). According to the results of **Study II**, it is likely that most emotional and behavioural difficulties are not associated with short-term sleep problems and that attention-deficit problems may be the first sign. It has not been possible in previous cross-sectional studies to separate short-term and long-term sleep problems due to the lack of available information about the child's sleep history, and it is therefore likely that emotional and behavioural outcomes in these studies are at least partially attributable to long-term sleep problems.

5.2.2 Long-term sleep problems

The results reported by Quach et al. (2009) are consistent with our findings indicating that persistent and current sleep problems predict a poorer health-related quality of life, problem behaviour, and language and learning difficulties, whereas resolved sleep problems have intermediate outcomes. Our study extends the results of Quach et al. (2009) in identifying associations between persistent sleep problems and a wide range of psychosocial difficulties. According to our results, children with persistent sleep problems may have severe psychosocial impairments that probably affect their everyday existence and reduce their quality of life: as in the case of children with only short-term sleep difficulties, attention and hyperactivity-related symptoms were the most common. However, whereas among those short-term difficulties the risk of experiencing comorbid attention and hyperactivity symptoms was almost nearly sevenfold, it was almost 14-fold among children with persistent difficulties. The propensity to express anxiety (13-fold risk) and exhibit aggressive behaviours (11-fold risk) are also commonly cited comorbid symptoms. Paavonen et al. (2003) reported in a follow-up study of a population-based sample of children ranging from 8–9 to 12–13 years of age that both current and persistent sleep disturbances were associated with a broad range of mental-health problems reported by teachers (Paavonen, Solantaus, Almqvist, & Aronen, 2003). Even though long-term sleep loss can cause widespread deterioration in neuronal functioning (see Jan et al., 2010, for a review) there is, some recent and rather encouraging evidence that treating adolescents with chronic sleep problems can significantly improve their cognitive performance (Dewald-Kaufmann, Oort, & Meijer, 2013). Still, neither the course of long-term sleep problems nor their relation to emotional and behavioural disturbances is fully understood. More studies are needed in order to determine why some children develop persistent sleep problems and others do not.

5.2.3 Poor sleep quality and its neural determinants

The aim in **Study IV** was to test the association between natural variation in sleep and sound encoding (P1, N2), pre-attentive change detection (MMN), and attention orienting (P3a) in normative school-age children. We found that P1 was not associated with sleep, which is consistent with results of previous studies on adults showing that P1 is persistently present even during sleep (Erwin & Buchwald, 1986; Paavilainen et al., 1987), and therefore might not be easily affected by sleep quality.

However, enhanced N2 was associated with poor sleep quality. Increasing the complexity of sounds has been found to enhance N2, which was interpreted as reflecting the need for neural resources for the analysis of complex sounds than simple ones (Čeponienė et al., 2005). One could speculate that the association of enhanced N2 amplitude with poor sleep quality implies that more neural resources are needed for processing sound properties after night of poor sleep. However, another plausible explanation is that children with poorer sleep quality find it difficult to focus their attention on the primary task (watching a film), and that their attention might have wandered to the auditory stimuli enhancing the N2 amplitude.

As was expected from the results of an earlier study on adults (Salmi et al., 2005), sleep quality had an effect on neural sound change-detection, too. However, according to our findings in **Study IV** poor sleep quality was associated with an enhanced MMN amplitude and had no statistically significant effect on P3a. A large MMN response is usually interpreted as an easy detection of sound change, but it can also reflect a stronger possibility that the change in sounds will result in the initiation of attention orientation towards the change, in other words, increased distractibility (Ahveninen et al., 2000). For example, previous studies have reported enhanced MMN amplitudes in adults and children with autism spectrum disorders for some sound-change types, which was interpreted to reflect hypersensitive sound processing (Kujala et al., 2013). An association between enhanced MMNs and increased distractibility caused by acute stress has been reported (Elling et al., 2011). Furthermore, there is evidence that major depressive disorder in children is associated with shortened MMN latencies, which in turn may reflect enhanced sensory sensitivity and attentional distractibility in these children (Lepistö et al., 2004).

In the current study sleep quality was associated with ERPs elicited by changes in sound duration but not with ERPs elicited by changes in sound frequency. Salmi et al. (2005) also found a stronger association between sleep quality and changes in sound duration than in sound frequency in adults. It may be that differences in the neural processing of sound frequency and sound duration explain these results. In other words, more integrative bilateral processing is required for duration encoding than for frequency encoding (Grimm, Roeber, Trujillo-Barreto, & Schroger, 2006; Molholm, Martinez, Ritter, Javitt, & Foxe, 2005; Rosburg, 2003).

Unlike Salmi et al. (2005) however, we found no significant association between sleep quality and P3a amplitude. This discrepancy could be related to the different age groups of under study: the degree of distractibility to novel environmental sounds due to poor sleep quality may differ in adults and children. Furthermore, the structure and morphology of ERP components are different in children and adults (Čeponienė et al., 2002; B. A. Martin, Shafer, Morr, Kreuzer, & Kurtzberg, 2003; Shafer, Morr, Kreuzer,

& Kurtzberg, 2000; Wetzel, Widmann, Berti, & Schroger, 2006). Thus, issues related to neural maturation might also explain the discrepant results of these two studies.

Whereas previous studies have shown that sleep quality influences sensory processing in children with major sleep problems such as OSAS, our results suggest that even sleep variation within the normal range may have effects on sensory information processing. Therefore, it would be vital to further investigate the associations of sleep quality with ERPs reflecting attention control and distractibility in childhood, and to assess the effects of these factors on school achievement. It would also be beneficial in future studies not only to study school achievement but also to incorporate some cognitive tests into the study protocol.

5.3 Validation of the SDSC for use among Finnish preschool-age children

The SDSC has been widely used in recent years (Ferreira et al., 2009; Romeo et al., 2013; Vlahandonis et al., 2013). The original SDSC scales were found suitable for preschool-age Finnish children, even though the internal consistency of some of them were lower than in the original validation study (Bruni et al., 1996) and in the recent validation study conducted in connection with translating SDSC into Brazilian Portuguese (Ferreira et al., 2009). However, there is one limitation in terms of applying it in studies on preschool and perhaps also school-age, namely the low variation in responses to question one: "*How many hours of sleep does your child get on most nights?*" Ninety-nine per cent of the preschool-age children and 96 per cent of the school-age children were reported to sleep between nine and 11 hours, which is the highest category in the SDSC. Therefore, it might be more informative, in particular with younger children, to add a category of above 11 hours as some young preschoolers may still sleep nearly 12 hours or more.

It was reported in the original study (Bruni et al., 1996) and in a recent study conducted among Italian preschool-age children (Romeo et al., 2013) that scoring 39 points or above was an indicator of sleep problems in the Total Problem Scale. Given the results of **Study II,** however a much higher cut-off point may be appropriate for Finnish preschool-age children. The recent validation study used different criteria for problematic sleep, however; the authors applied standardized T-scores with the following formula [50 + (value – mean)/standard deviation * 10] and scoring above

50was used as an indicator of a sleep problem (Romeo et al., 2013). Using a cut-off point 50 means that 33 per cent of the children were considered to have sleep problems, which is rather unlikely and diagnostically uninformative. A score of 46 points used to describe the level of problematic sleep constitutes an upper quartile of the population, which is still a rather high proportion, although in the original validation study children scoring above the upper quartile had similar scores on the SDSC as children who had been clinically diagnosed with a significant sleep disorder (Bruni et al., 1996).

5.4 Limitations

Even though the results support the notion that sleep is important, there are limitations to be considered before they can be generalised. The response rate in the follow-up study was moderate: it was 65 per cent (n = 904) in the first phase (**Study I**), of which 53 per cent (n = 481) also responded in **Study II** and 52 per cent (n = 470) responded in **Study III**. Of the original sample of 1,400 children, the response rate in both phases was 34 per cent (**studies II & III**), which may cause some bias in the results. The probable direction of this bias is that parents of children with sleep difficulties are more likely to respond surveys such as this than parents whose children do not experience such difficulties. The fact that the baseline prevalence rate for any sleep problem in the study population was 45 per cent (n = 904), whereas among those who also returned the questionnaire at follow-up (n = 481), 49 per cent of the children had had at least one sleep problem at baseline, indicates that this may be the case. However, when we compared the preschool-age SDSC scales of the whole group (n = 904) with those of the children who were also included in the follow-up (n = 481), we found no differences.

Our participants lived in the Helsinki metropolitan area, thus limiting the generalisation of the results to populations living in smaller towns and rural areas. Moreover, even though the sample size could be considered rather large, the modest response rate may have biased the results, therefore caution should be exercised in their generalisation. Another limitation is that the study only included the parental evaluation of children’s sleep problems, which is inevitable because data used in **Studies I-III** are based on epidemiological population surveys. The absence of the children’s own view may have some impact on the identified decline in sleep problems from preschool to school-age, as parents may be less aware of their children´s sleep patterns as they grow older. According to Paavonen and colleagues, a significant proportion of children’s sleep problems may go unnoticed (Paavonen et al., 2000). Similarly, in reality the persistence of problems could be even more substantial than the results of this study imply. Defining a sleep problem/disturbance is difficult and somewhat arbitrary when subjective sleep questionnaires are used. Here, we report on specific problems such as ‘difficulty in falling asleep’ occurring at least three times a week, and compare the results with those of earlier studies using similar specific questions and definitions. We also report on sleep disturbance, which applies to children having multiple sleep problems (e.g. with the highest total scores on the SDSC), and was used when evaluating the persistence of sleep disturbance from preschool to school age. Sleep disturbance was not verified on more objective measures such as actigraphy or polysomnography. However, given the limitations of the approach, parental reporting is usually the only available and useful source of information in large samples of young children (Gregory et al., 2011).

With regards to interpreting the results of **Study IV**, it should be borne in mind that the sample size is modest, including only fifteen children, and that such sample sizes always raise questions concerning the generalizability of the results to the entire population. Second, actigraphy data were collected during three consecutive nights prior to the EEG recording in order to obtain quantitative estimations of sleep quality and quantity. A longer time period would give more reliable estimation of sleep. Even though these limitations preclude the drawing of the definitive conclusions, however, the results we obtained are in line with a still small but yet constantly growing body of evidence concerning the adverse effects of sleep problems on early stages of neurocognitive processing.

6. Clinical implications

A high frequency of sleep-related problems is common among preschool-age children: almost 50 per cent of parents in our sample noted some such problems in their children. The effects are not limited to the children, but also spread to parents and perhaps siblings as well: frequent waking and struggles at bedtime can be wearing on the whole family. Problematic sleep may endanger children’s optimal development and could also have an adverse effect on the interaction between child and parent given that sleeping problems in children often require the parent to be awake during the night as well. Sleep problems are quite persistent at preschool age, and do not get resolved before school age in over one third of children. However, children regarded as good sleepers in preschool years seldom develop sleep difficulties at school age, which indicates the need to identify and treat potential problems during the preschool period in particular. If such problems are not resolved before school age they may adversely affect the on child’s behavioural and emotional development.

According to the results reported in this thesis, not only do long-terms sleep problems have adverse outcomes, even modest problems related to sleep quality may also affect the allocation of resources available to meet auditory-processing and attention demands. Since it appears that sleep quality has an effect on neural processes related to the development of language skills and increased distractibility, poor sleep may have an adverse effect on concentration at school and therefore indirectly weaken performance. Given the consequences of long term sleep problems identified in epidemiological **Studies I-III** and the association between poor sleep and pronounced distractibility found in **Study IV** it would be beneficial to include sleep-quality evaluation as a routine check in attempts to resolve emotional and behavioural difficulties among children at school.

7. References

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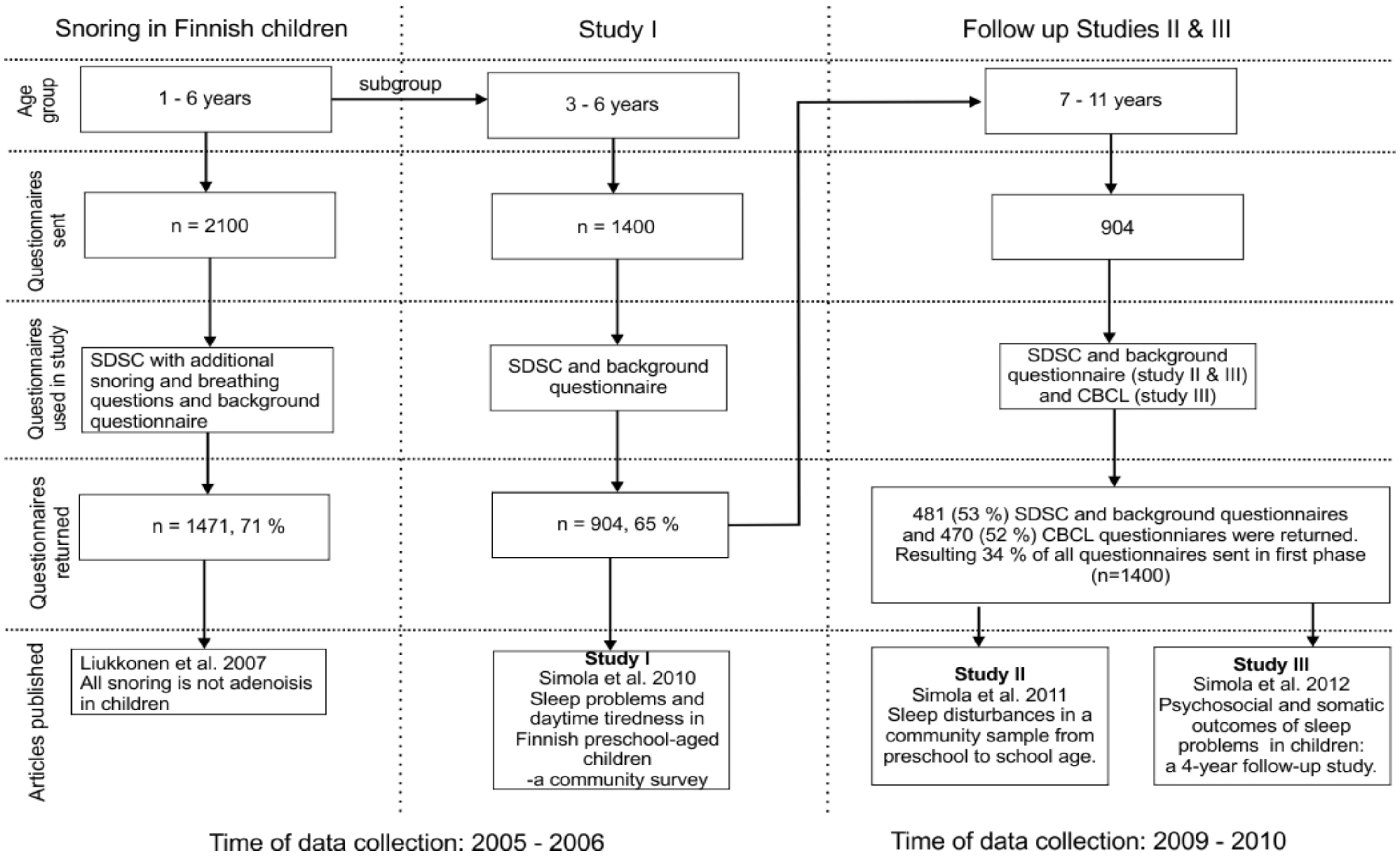
8. Appendix A



Appendix A. Flow diagram created to clarify participation and response rates in **studies I – III**