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Sleep and Chronotype in Adolescents

- a Chronobiological Field-Study -

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Dedicated to Felix

Table of Contents

Boys in bed, girls in bed
All now go to sleep
Sleep, sweet dreams
Wake to a new today tomorrow

R.E.M. It's a free world baby (1992)

1 Introduction

1.1 Chronobiology and Biological Rhythms

Everything has Rhythm. Everything Dances.

Maya Angelou (1928)

Every living organism, from the most simple protozoan to the most complex plant or animal, including humans, has inherent clock mechanisms that reign its place and functioning in time (Roenneberg and Merrow 2003; Kuhlman, Mackey et al. 2007). Among the first to realise that living organisms arrange themselves in advantageous environmental conditions in order to be provided with the best setting for survival and reproduction was Darwin (1859). He found evolution to occur via selection of randomly appearing genetic mutations that would provide advantages over other species. Almost 100 years later Hutchinson (1957) termed the unique and advantageous circumstance of different species' settlement as the "ecological niche". Modern chronobiology has enlarged the frame of this term by adding the concept of a temporal niche of organisms. Every organism has its individual arrangement of activity times and rest times. In this way, advantages can be gained e.g. when being active at times that provide the best frame for food intake, photosynthesis or mating, at the same time being minimally endangered by predators (Roenneberg 2010). Rather than only being divided into rest and activity times, life itself appears to be profoundly rhythmic, as in more and more physiological processes, rhythmicity is being found to play a vital role (Arendt 1998). In the human being, among the most basic of such rhythmic processes are heart rate, respiratory rate, blood pressure, the ovarian cycle, activity bursts, hormone secretion and sleep phases (Aschoff 1965; Zulley and Knab 2003; Moser, Fruhwirth et al. 2006).

The first scientist who invented a new terminology of rhythms was Halberg (1959). These, rather than being perfectly exact are "circa-rhythms", corresponding roughly with the earth's rhythms of moon and sun. Chronobiology investigates about biological rhythms. These may be circannual- (rhythms of approximately one year), circalu-

nar- (rhythms of approximately one lunar cycle of 29.5 days), circatidal- (rhythms of approximately one ocean tide - usually 12 h and 25 min), infradian- (rhythms with a period longer than 24 h), ultradian- (rhythms with a period shorter than 24 h) or circadian (rhythms of approximately one day)(Refinetti 2011). The present study will engage in an inquiry into several aspects of circadian sleep-wake rhythms in human adolescents.

1.2 Circadian Rhythms in Humans

Es gibt ein großes und doch ganz alltägliches Geheimnis.
Alle Menschen haben daran teil, jeder kennt es,
aber die wenigsten denken je darüber nach.
Die meisten Leute nehmen es einfach so hin und wundern sich kein bisschen darüber.
Dieses Geheimnis ist die Zeit.

Michael Ende, Momo (1973)

In his novel „Momo“ (1973/2009), Ende continues, referring to “the mystery of time” as something every person carries within themselves. Science has shown that this statement beautifully approaches truth. Like all living creatures, the human being has an internal ability of measuring time within the body (Roenneberg 2010). According to Roenneberg, this “clock” governs not only sleeping habits, but all bodily functions, such as blood pressure, hormone levels and body temperature, to name but a few. While every cell has several clock mechanisms which are governed by numerous genes (Young and Kay 2001; Roenneberg and Merrow 2003), the master clock consists of the **suprachiasmatic nuclei** (SCN), located bilaterally in the anterior hypothalamus, above the optic chiasm (Fuller, Gooley et al. 2006; Moore 2007). These circadian oscillators contain approximately 20.000 clock neurons in their ventrolateral division, many of which are spontaneous oscillators. The period length of the SCN approximately approaches a length of 24 hours, within a range from 22 to 28 hours per day (Ospeck, Coffey et al. 2009). This phenomenon was first demonstrated by Aschoff et al. (1965), who showed that participants in temporal isolation, i.e. who were completely deprived of any external “*zeitgeber*” (German for “time-giver”) (Golombek and Rosenstein 2010)

– and thus of any factor that might help to orientate within time, like sunlight, clocks, noise, or social contacts - (Roenneberg, Wirz-Justice et al. 2003) developed their own day-lengths that took sometimes up to 30 hours per day. Those experiments showed that humans have free-running periods which endure even in the absence of any external zeitgeber. The SCN, rather than obtruding their own rhythm to the organism, serve as coordinating agents, exerting influence on numerous circadian clocks in the body, throughout several systems, down to a cellular level of circadian metabolism. On this level, several genes have been identified to be of importance for cellular controlling mechanisms (Hastings, Maywood et al. 2008). When the SCN are lesioned, sleep-wake circadian rhythms are found to become entirely erratic (Lee, Swanson et al. 2009).

Beyond coordinating numerous physiological functions, the main role of the SCN is to synchronise the individual with external time, responding to the main zeitgeber, sunlight, in alternation with darkness (Aschoff 1965; Roenneberg, Wirz-Justice et al. 2003; Reinoso-Suarez, de Andres et al. 2011). The inner retina possesses intrinsically photosensitive retinal ganglion cells (ipRGC), expressing the photopigment melanopsin which enables them to respond to light (Berson 2003; Rollag, Berson et al. 2003). Via the retino-hypothalamic tract, the SCN receive their input (Kumar and Rani 1999; Hannibal and Fahrenkrug 2006), hence being entrained to the day/night cycle (Golombek and Rosenstein 2010; Pickard and Sollars 2010). In summary the SCN ensure that "physiology across the entire organism is temporally integrated and thus maximally adapted" (Hastings, Maywood et al. 2008).

1.2.1 Chronotype

"Chronotype refers to the point in time when an individual's endogenous circadian clock synchronises (entrains) to the 24 hour day." (Roenneberg, Kuehnle et al. 2004). Along with genetic factors, it depends on different environmental cues or individual characteristics, such as on age (Roenneberg, Wirz-Justice et al. 2003). In his book „Wie wir ticken " (2010), Roenneberg states that: „different people can be entirely different chronotypes – in extreme cases the discrepancy may account up to 12 hours". A per-

sons' chronotype is computed as "mid sleep on free days" (MSF), standing for the mid-point between sleep onset and sleep end, when sleeping time can be chosen freely according to physiological needs (Roenneberg, Kuehnle et al. 2007). One important note on this point is that chronotype is independent of sleep duration. As such, among early types, there are as many long and short sleepers, as among normal and late types (Roenneberg and Merrow 2007). Since late chronotypes often develop a sleep deficit throughout the week when having to get up relatively early, and early chronotypes tend to develop this deficit on the weekends due to relatively late sleep onset times when socializing with friends, a correction for MSF has been developed (MSF sleep corrected / MSF_{sc}) to account for this interference factor. MSF_{sc} is the most important one among parameters determined by the Munich Chronotype Questionnaire (MCTQ) (Juda 2010), which will be explained in detail in "Materials and Methods". The distribution of chonotypes in central Europe is "almost normal, with a slight over-representation of later chronotypes" (Roenneberg, Kuehnle et al. 2007).

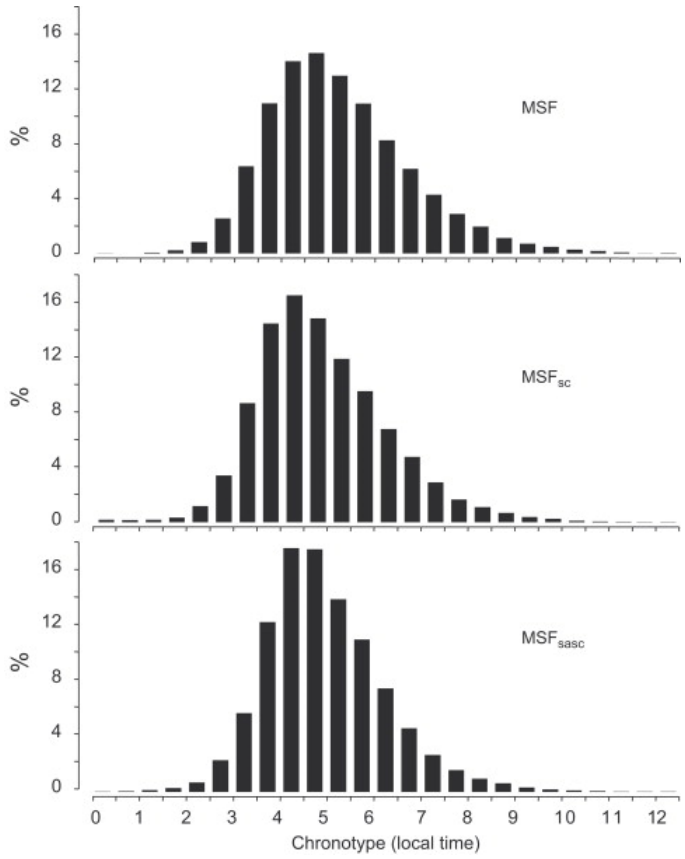

Figure 1.1: Distributions of MSF, MSFsc and MSFsasc (from Roenneberg et al. 2007)

Talking about early and late chronotypes it is important to notice that most individuals are situated in between these two extremes (Roenneberg, Kuehnle et al. 2007). The MSF_{sc} of an average chronotype is 4.5, which implies that such a person sleeps e.g. from about 12:30 p.m. to about 8:30 a.m. (assuming a sleep need of 8 h), having their point of mid-sleep at 4:30 a.m., as long as there are no social obligations, such as early

work- or school start times. (Roenneberg, Wirz-Justice et al. 2003; Roenneberg, Kuehnle et al. 2007).

In contrast to free days, average wake-up time is 2 hours earlier on workdays, while the differences in sleep onset between work days and free days are much smaller (Roenneberg, Kuehnle et al. 2007).

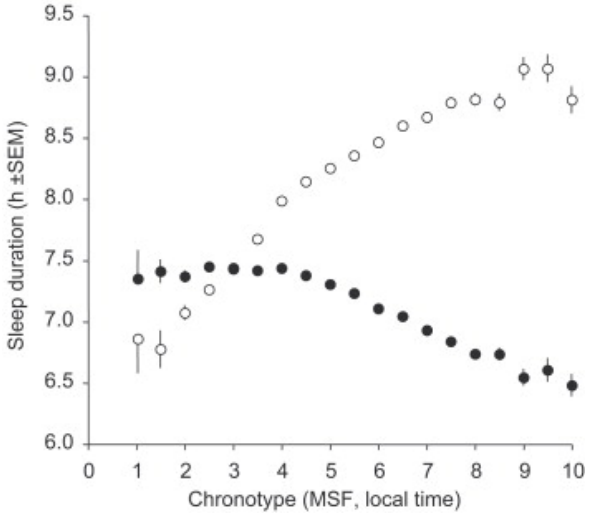

Figure 1.2: "Relationship between chronotype (MSF) and sleep duration analysed separately for work- and free days (filled and open circles). Early chronotypes are sleep deprived on free days while late chronotypes sleep less than their weekly average on workdays. People who sleep voluntarily approximately between 11:00 p.m. and 6:00 a.m. are the only chronotypes who show no difference in sleep duration between work and free days. Vertical bars represent the SEM in each category" (Figure and subtext by Roenneberg et al. 2007).

Later chronotypes tend to sleep longer on weekends than normal- and early chronotypes, as they have to catch up on the sleep-deficit they accumulated throughout work- or school days. According to Roenneberg et al. (2003) a person's chronotype is ruled by a solar-, a biological- and a social clock, with the former two being considerably stronger zeitgebers, than the latter one (Roenneberg and Merrow 2007). Therefore a person's chronotype cannot be changed merely by "getting used" to certain time schedules.

1.2.2 The Circadian Clock in Adolescence

Adolescents are commonly unable to change their sleep-waking schedules by going to bed earlier than they might wish, as it is often required by parents and teaching staff. Whereas children and elderly people tend to be early chronotypes, adolescents tend to

be later types. This fact, being rather familiar to most parents, could be demonstrated by Roenneberg et al. (2004). At the age of 12, with the onset of puberty, adolescents start becoming later (Randler 2009), reaching the peak of their "lateness" around the age of 20 (Roenneberg, Kuehnle et al. 2004). Roenneberg et al. suggest this change of internal rhythm to be "the first biological marker to indicate the end of adolescence". Whereas women have been shown to reach their maximal lateness around an age of 19.5 years, men reach this stage at an average age of 20.9 years. They then remain slightly later chronotypes than women, until an average age of 50, when no more difference is observed between both. Despite the physiological age dependent fluctuation in lateness throughout a person's life, an individual's chronotype is usually stable in relation to other subjects of the same age and sex throughout life. To correct for influences of sex and age effects among chronotypes, another correction of MSF_{sc} has been developed by Juda et al. (2010). This is termed the MSF sex age sleep corrected (MSF_{sasc}).

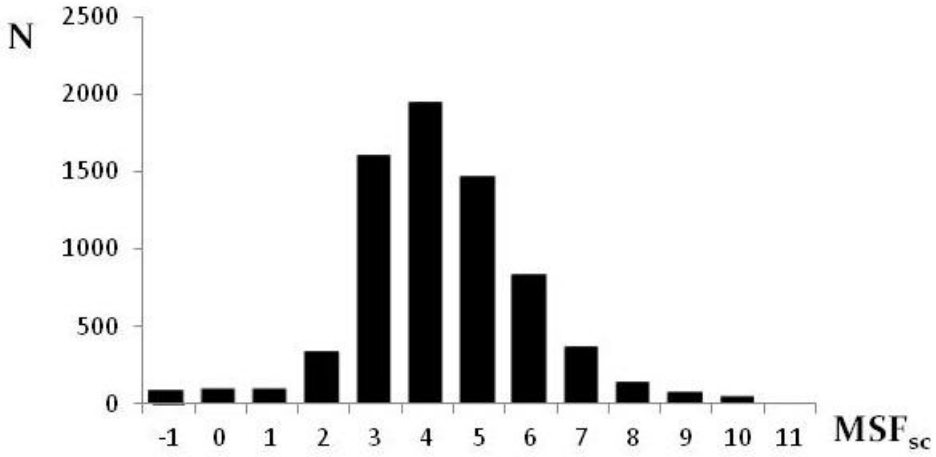

Figure 1.3: MSFsc-distribution among 14–19 year olds; modified after Roenneberg (2011) - unpublished Data

1.3 Sleep

Curcio et al. (2006) describe sleep as "an active, repetitive and reversible process serving several different functions, such as repair and growth, memory consolidation, and restorative processes". Thus behavioural, physiological and neurocognitive processes are involved in sleeping, as well as immunological functions (Lange and Born 2011), although the extents and mechanisms of these functions have not been fully under-

stood yet (Curcio, Ferrara et al. 2006; Fuller, Gooley et al. 2006; Diekelmann and Born 2010; Smetacek 2010). Sleep deprivation clearly impairs the ability to acquire new memories (Benca, Duncan et al. 2009), although also the exact mechanisms of memory-formation are still unknown (Kopasz, Loessl et al. 2010).

1.3.1 Anatomy and Physiology of Sleep

The anatomy of sleep consists of a complex interplay of activating and inhibiting feedback loops between several centres in the upper brain stem, and the cortex. Arousal and its inhibition are mediated mainly via the formatio reticularis in the ascending arousal system (ARAS) through neural projections to the thalamus and basal forebrain (Trepel 2004; Saper, Scammell et al. 2005). There are two pathways through which cortical arousal and inhibition is enabled. Via the dorsal route, cholinergic neurons of the laterodorsal and pedunculopontine tegmental nuclei of the mesopontine tegmentum serve to excite thalamocortical neurons and the reticular nucleus (Fuller, Gooley et al. 2006). The ventral route involves the hypothalamus and basal forebrain, originating in the locus coeruleus (noradrenergic), raphe nuclei (serotoninergic), ventral periaqueductal grey matter (dopaminergic), tuberomamillary nucleus (histaminergic) and lateral hypothalamus (via orexin and melanin-concentrating hormone) (Saper, Scammell et al. 2005). According to Fuller (2006), "neurons in all of these cell groups fire more during wakefulness than during non-REM-sleep, and show virtually no activity during REM sleep." A central role in the inhibition of the neural circuits of the ARAS is considered to be played by the ventrolateral preoptic nucleus. This inhibition occurs between ventrolateral preoptic nucleus and ARAS, and vice versa, in what is called by Saper et al. (2005) a "flip-flop-switch-design". This system is indirectly stabilised by orexinergic neurons and neurons containing melanin-concentrating hormone of the lateral hypothalamus, preventing a spontaneous switch of activation/inhibition, as it occurs e.g. in narcolepsy (Saper, Scammell et al. 2005).

The above named cerebral circuits have been displayed in detail by Fuller et al. (2006), as shown in the figure below:

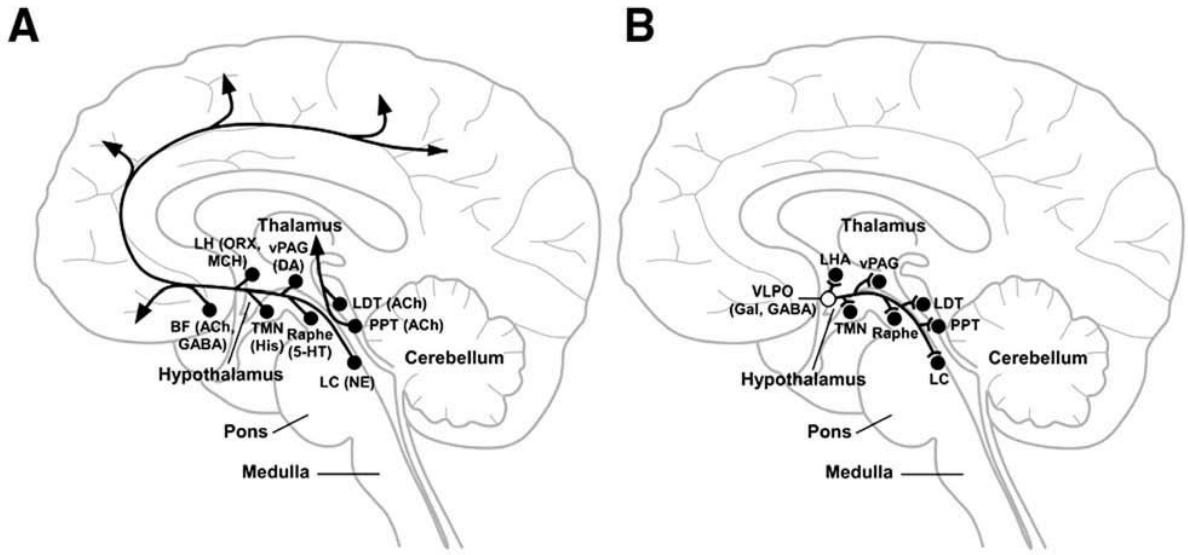

Figure 1.4: "(A) The ascending arousal system consists of noradrenergic neurons of the locus coeruleus (LC), cholinergic neurons in the pedunculopontine and laterodorsal tegmental (PPT/LDT) nuclei, serotoninergic neurons in the dorsal raphe nucleus (DR), dopaminergic neurons of the ventral periaqueductal gray matter (vPAG), and histaminergic neurons of the tuberomammillary nucleus (TMN). These systems produce cortical arousal via 2 pathways: a dorsal route through the thalamus and a ventral route through the hypothalamus and basal forebrain. The latter pathway receives contributions from the orexin (ORX) and melanin-concentrating hormone (MCH) neurons of the lateral hypothalamic (LH) area as well as from GABAergic or ACh neurons of the basal forebrain (BF). (B) A schematic of the projections of the ventrolateral preoptic nucleus (VLPO; open circle) to the main components of the ascending arousal system. The VLPO neurons are primarily active during sleep and contain the inhibitory transmitters GABA and galanin." (Figure and subtext from Fuller et al. 2006)

While initiating sleep the ARAS also slows down the activity of spinal neurons that innervate skeletal muscle tissue. This causes a decreased tone of skeletal muscle (Sibley, Mochizuki et al. 2010), leading to a decrease in postural uprightness.

Upon a darkness-stimulus from the retina, the SCN stimulates the expression of melatonin from the pineal gland. This expression usually occurs in the (subjective) evening (Fuller, Gooley et al. 2006). It leads to an activation of the hypothalamus. This in turn decreases its expression of histamine and orexin, two substances, usually leading to increased alertness.

One major substance involved in the cessation of sleep is cortisol. Its expression slowly increases throughout the second half of sleep (Payne and Nadel 2004), with a steep increase before the physiologically-, or mentally anticipated time of waking up (Akerstedt, Billiard et al. 2002). There are numerous other somatic substances, causing increased sleep pressure. One of these is adenosine, which derives from metabolic processes involved in physical exercise (Fuller, Gooley et al. 2006). Throughout febrile

disease states, inflammatory mediators, such as interleukin-1, interleukin-6 and tumor-necrosis factor-alpha are known to cause an augmentation of tiredness and sleep (Bieger 2010).

Homoeostatic regulation of sleep has been proposed by Borbély (1984) to be explained by a two-process-model. In this model, sleep pressure (process S), which builds up with increased duration of wakefulness, interacts with an intrinsic circadian process (process C), which is independent of sleep- and wake-timing. A marker for the build-up of process S is nowadays considered to be EEG delta power, which increases simultaneously with sleep pressure (Fuller, Gooley et al. 2006). Edgar et al. (1993) amplified Borbély's model, suggesting that the SCN triggers and maintaines states of wakefulness and sleep, antagonising process S during the subjective daytime. Lee et al. (2009) demonstrated that the SCN not only accounts for the occurrence of sleep itself, but also for the occurrence of specific sleep stages as a circadian pacemaker.

1.3.2 Sleep-EEG and Sleep Stages

The classical sleep-EEG is recorded via at least 5 electrodes that are distributed on the frontopolar, temporal and the occipital regions of the scalp (Zschocke 2002). In conventional polysomnography (PSG), this is usually combined with electrooculogram, electromusculogram, electrocardiogram and measurements of body position. Additional measures may be added such as thoracic and abdominal breath-excursions, intranasal airflow, leg-movements, penile erection and peripheral oxygen-saturation (Keenan 1992), among others.

In awake subjects, the EEG usually displays desynchronised, high-frequency, low amplitude beta waves within a range of 14-30Hz (Fuller, Gooley et al. 2006). This changes as soon as the relaxed subject closes their eyes, which leads to an immediate change to alpha waves, ranging from 8- to 12 Hz. These waves can preferentially be measured by occipital electrodes (Zschocke 2002; Toscani, Marzi et al. 2010). The EEG frequency begins to slow when the individual falls asleep. In sleep stage 1, conscious awareness of the surroundings slowly disappears and in the EEG, theta waves between 4 and 7 Hz predominate. The increased amplitude of EEG waves reflects the heightening syn-

chrony of cortical neurons' firing. This synchronisation increases with depth of sleep. The second sleep stage is characterised by an increased appearance of sleep spindles and K-complexes (Benbadis and Rielo 2010; Perez, Roberts et al. 2010). It goes along with a complete withdrawal from external awareness. Stages 3 and 4 are usually referred to- and summarised as slow wave sleep (SWS). In this stage, delta waves predominate, ranging from 1-3 Hz. These waves reflect the maximally synchronised oscillations of thalamocortical circuit activity (Zschocke 2002). Fuller et al. (2006) state that: "the neocortex is also capable of generating autonomous delta wave activity." In contrast to the non-REM sleep stages, EEG-activity in REM-sleep is rather similar to that of the awake state or stage 1 sleep (Fuller, Gooley et al. 2006; Benbadis and Rielo 2010). The picture seen in REM is thus one of high frequency, low-amplitude activity (Feinberg and Campbell 2010). However, an essential difference to waking is seen in the electroocculogram (EOG), revealing rapid eye movements and the electromusculogram (EMG) showing an intense atony of the skeletal muscles throughout REM sleep. Fuller et al. (2006) remark that common EEG scalp recordings show only a partial picture, since they measure solely cortical electrical activity, neglecting activity in subcortical areas.

According to Benbadis and Rielo (2010), healthy young adults spend 3-5% of their sleep time in stage 1, 50-60% in stage 2, and 10-20% in stages 3 and 4, whereas REM sleep occupies 10-25%.

Roenneberg et al. (2007) found their largest binned group to sleep 7.5-8 hours on free days. Notwithstanding this group was made up of only 15.5% of the sample population. 50.5% slept even longer. Sleep durations on free days are varied among individuals within a normal-distribution range, just as widely as chronotype.

The first third of a night's sleep is usually dominated by light sleep, alternating with SWS (Voss 2004). In the following parts of the night, the abundance of SWS decreases and REM sleep increases, until the last third of the night, in which light sleep alternates with REM sleep. Among healthy, well-rested individuals the latency to a night's first episode of REM-sleep (REM latency) takes about 90 minutes (Zschocke 2002; Carskadon and Dement 2005). Throughout a sleeping episode, numerous arousals are normally observed. When such arousals do not last longer than 5 seconds, they are

referred to as microarousals. These often occur at intersections between deeper- and lighter stages of NREM sleep, or in the transition-phase from REM sleep into waking. Voss et al. (2004) explain the purpose of these frequent shifts between phases of high and low arousal thresholds as allowing the "periodic screening of the sleep environment for danger signals." They are always coupled to the possibility of an extended awakening, if an accordant external stimulus occurs (Akerstedt, Billiard et al. 2002; Zschocke 2002).

According to Carscadon et al. (2005) healthy adults begin sleeping through stage 1 sleep. In the first sleep cycle, NREM sleep quickly deepens to stage 4, then becoming lighter again, until it ends in REM sleep. An individual then moves through several sleep cycles of approximately 90-minutes in which NREM and REM alternate. Children are reported to have 5-6 sleep cycles per night (Carskadon and Dement 2005) while among adults, 4-6 sleep cycles per night are reported (Borbely 1984; Sander and Schönknecht 2011).

1.3.3 Sleeping into Adulthood: Characteristics of Sleep in Adolescence

Keeping in mind the large scale of individual difference in sleep duration (Roenneberg, Kuehnle et al. 2007), adolescents require on average 9 hours of sleep per night. Unfortunately this requirement can often not be met and so the average sleep duration actually reported e.g. in the USA is no more than 7.53 hours (Gangwisch, Babiss et al. 2010). Sleep duration is increased on the weekends, as the deficit accumulated throughout the week is being caught up on. It is highly suspected that adolescents, rather than not being willing to go to sleep early due to social "commitments" like meeting peers in the evening, rather might be unable to fall asleep early due to the impact of their circadian clocks (Roenneberg 2010).

In their review on adolescent sleep Crowley et al. (2007) cite numerous studies reporting that during adolescence bedtime progressively delays. According to Roenneberg et al. (2003), this delay accounts up to almost 3 h on free days as compared to school days. Crowley et al. (2007) state that the difference between weekend- and school-time bedtimes is between 1 and 2 hours, enlarging with increasing age. In several stud-

ies reviewed by them, large percentages of students were found to suffer from severe tiredness throughout the days when going to school. These observations are in line with Roenneberg et al.'s (2004) finding, that chronotype is progressively delayed in adolescence. Researchers who engage into the sleep of adolescents commonly request later school start times by which the physiological sleep needs of students could be met properly (Carskadon, Wolfson et al. 1998; Roenneberg, Kuehnle et al. 2004; Wittmann, Dinich et al. 2006; Crowley, Acebo et al. 2007; Randler 2009; Dewald, Meijer et al. 2010). Some researchers also suspect that in addition to insufficient sleep, there may be an endogenous sleepiness in this age group, possibly being based on the tremendous cerebral changes taking place (Carskadon, Harvey et al. 1980; Feinberg and Campbell 2010).

The sleep stage affected mostly by age is slow wave sleep. Being maximal in young children, it decreases by almost 40% in the second decade of life. Feinberg and Campbell (2010) describe a marked decline in delta- and theta power between the age of 11 and 17 years. Simultaneously, stage 2 sleep is seen to increase (Tarokh and Carskadon 2010). Overall a significant decrease of EEG power in all sleep stages is observable throughout the second decade of life. These changes in adolescent sleep suggest a fundamental reorganisation (i.e., maturation) of the brain throughout adolescence. (Feinberg and Campbell 2010). Simultaneously synaptic density and cortical metabolic rate decline, while myelination of cerebral axons increases (Whitford, Rennie et al. 2007). Throughout these processes, cortical thickness decreases by 10- to 20%. Since the amplitudes of EEG waves are proportional to the amount of cortical neurons changing their membrane potentials, the decline in overall EEG power is regarded as being caused by the decline in neuronal mass (Whitford, Rennie et al. 2007; Feinberg and Campbell 2010; Tarokh, Carskadon et al. 2010).

1.4 "Social Jetlag" and its Effects

The amount of sleep required by the average person is five minutes more.

Wilson Mizner (1876 - 1936)

Whoever has ever flown across several times zones to the east or west has probably made the experience that the internal clock is not immediately used to local time at destination. This effect, known as "jetlag" takes place when there is a discrepancy between one's internal, biological time and social time. It is then termed a "social jetlag" (Roenneberg, Wirz-Justice et al. 2003; Wittmann, Dinich et al. 2006). This effect is correlated significantly with chronotype: later chronotypes, adhering to a conservative time-schedule throughout the working-week, tend to develop higher sleep deficits than early types, and thus experience a stronger social jetlag. Among age groups, this effect is maximal in adolescents due to their increased tendency for lateness (Roenneberg, Kuehnle et al. 2004) clashing with consistently early school times in Germany at around 8 a.m..

Social jetlag is calculated as "the absolute difference between mid-sleep on work days (MSW) and mid sleep on free days (MSF): $\Delta MS = |MSF-MSW|$." (Wittmann, Dinich et al. 2006).

It is known that shift workers, who constantly live against their circadian clocks have higher risks of developing several illnesses like cancer and heart disease (Arendt 2010). There is also evidence that late chronotypes are more prone to diseases when living according to a relatively early schedule, which is coherent with the normal German custom of beginning work at 8 a.m. (Wittmann, Dinich et al. 2006). Not enough on this, later chronotypes even appear to possess minor career chances than earlier ones, as Randler (2010) points out in his paper with the ostensive title: "The early bird really does get the worm".

In adolescents, sleep has been shown to be essential for wellbeing, health, cognition and school performance (Anderson, Storfer-Isser et al. 2009; Randler and Bilger 2009; Dewald, Meijer et al. 2010). The list of effects from poor sleep, late bedtimes and early rising on adolescents ranges from decreased learning capacity and school performance

(Fallone, Owens et al. 2002; Wolfson and Carskadon 2003; Curcio, Ferrara et al. 2006) to an increase of smoking (Wittmann, Dinich et al. 2006), drug abuse (Mednick, Christakis et al. 2010; Taylor and Bramoweth 2010; Yen, King et al. 2010), higher rates of depression and psychiatric disorders (Roane and Taylor 2008; Benca, Duncan et al. 2009; Gangwisch, Babiss et al. 2010; Hale 2010; Gruber, Wiebe et al. 2011) as well as higher rates of traffic accidents (Pizza, Contardi et al. 2010; Taylor and Bramoweth 2010). According to Weiss et al. (2010), sleep deficit and thereby social jetlag also contributes significantly to being overweight in adolescents.

1.5 Adolescents' Sleep – a Health Care Subject

Common health prevention programs have so far basically addressed the subjects exercise, nutrition, prevention of alcohol-, nicotine- and drug abuse and use of electronic media (Bergmann, Eis et al. 2008). Lately another main pillar of preventive health care is coming up among the public: healthy sleep. This subject is especially considered to be of importance by the German Federal Ministry of Education and Research (Stern, Grabner et al. 2007). Here it states one pillar among others in the research into learning and cognition. This is regarded to be crucial for a future optimisation of educational institutions. Among research-questions being addressed since a few years are thus such as: in what ways may too-early schedules be harmful to adolescents?

As Dewald et al. (2010) report in a meta-analysis, "sleepiness showed the strongest relation to school performance, followed by sleep quality and sleep duration" among adolescents. In accordance with Curcio et al. (2006) and Crowley et al. (2007) the authors highlight the need for more experimental and longitudinal studies that aim at clarifying the important fundamentals of adequate sleep in adolescence in order to develop programs that may optimise sleep-patterns, thereby improving school performance.

The term "adolescence" has been chosen, rather than "puberty" since it refers to the maturation of social and cognitive behaviours in a broader way (Sisk and Foster 2004). The concept of puberty in contrast, rather refers to a demarcation of the entrance into

sexual maturity (Oerterer and Montada 2002). In general, when referring to "adolescence", a span from 11 to 21 years of age is designated.

Although we know that adolescents tend to be the latest „night owls" in society, not a lot of studies have been carried out on their sleep structure yet. (Roenneberg, Kuehnle et al. 2007). As has been pointed out above, they are also the age group requiring the highest amount of sleep in society, yet actually obtaining the least amount (Carskadon, Wolfson et al. 1998). For this reason the further exploration of adolescents' sleep and chronotype is considered to be highly important.

The present study, since being conducted in a field-setting, has several limitations, as will be pointed out in the discussion. Yet it represents a first step in examining adolescent sleep and chronotype in close-to-real life conditions, within a financially practicable framework. As a positive "side effect", the conduction of this study has a health-preventive function, by educating adolescents about the role of sleep in their lives and sensitizing them to their own sleeping behaviour.

1.6 Aims of this Study

Adolescents spend large amounts of their time at school studying, in order to understand complex matters and to memorise numerous curricular contents. Since it is well known that sleep has an impact on learning and memorising (Kopasz, Loessl et al. 2010) and that chronotype often has an impact on the amount of sleep an individual attains in the working society (Roenneberg, Kuehnle et al. 2007), there is an immense need to optimise circumstances for adolescents at school in order to give them a serious chance to prepare for their later lives. Consequently, it is worthwhile to broaden research into the subject of sleep in adolescents. The present study ought to play a conductive part in providing one building block on the way of developing a basis for such research by pioneering a method, via which further studies may be performed expediently.

The **overriding aim** of this study is to investigate how well chronotype and sleep profiles of adolescents may be examined in a field setting, using an explorative approach.

To do so, students' sleep profiles are to be examined in a mobile sleep lab (or "sleep mobile") that will be based at their school. This study also aims at elucidating the relationship between chronotype and sleep profiles. To date, such data are still lacking. The sleep parameters that are to be examined in their overall duration and its relationship with chronotype are: total sleep duration, sleep latency, time awake after sleep onset, light sleep, deep sleep and REM sleep. Prior to recording sleep profiles, chronotypes will be measured by the Munich Chronotype Questionnaire (MCTQ). In addition, sleep logs will be kept by the participants, in order to validate MCTQ-results and assess sleeping behaviour around the study-period. Since the present study is supposed to pave the way for further similar studies that might look at related subjects in more detail, an easy to use, efficient and cost-effective way of realisation was sought. Therefore the mobile, automated system "Zeo®" was elected as a convenient means of measuring EEG.

The results-part of the present study will consist of two divisions: in the descriptive part, MCTQ-measurements, sleep-log measurements and sleep parameters as measured by Zeo® in the sleep mobile will be displayed. In the second part, analyses of sleep parameters and MCTQ-parameters such as chronotype and social jetlag will take place.

The **main question** of this thesis is weather common chronobiological expectations about sleep timing and –phases can be replicated in the sleep-mobile-setting of the present study, using Zeo®-EEGs. In addition to this explorative approach two hypotheses are posed, as follows:

Later chronotypes will be observed to fall asleep later in the sleep mobile than earlier ones, and wake up later (**hypothesis 1**).

Regarding the total sleep duration, another hypothesis is generated based on reasoning about homoeostatic mechanisms of sleep regulation. Later chronotypes are expected to accumulate a greater sleep deficiency throughout school days, which is why they have to catch up on this deficit on the weekend. For this reason they should be observed to spend more time overall sleeping in the sleep mobile, than earlier chronotypes (**hypothesis 2**).

Further questions of interest are:

- Is there any correlation between chronotype and sleep parameters? If this was the case, is there any difference between the earlier- and the later chronotype-group?
- How are correlations among the durations of the measured sleep-phases, such as total sleep, REM-, light-, deep sleep and time awake after sleep onset?
- How is the sleep mobile timing in relation to real life sleep timing? Are sleep onset and sleep end as measured by Zeo® in the sleep mobile consistent with a circular sleep window that will be generated from MCTQ-data?
- Is the first night effect observed in the sleep mobile, like in common sleep lab studies?

The latter question is being posed since in standard sleep labs, commonly a first night effect is observed. This effect usually shows up most evidently through increased sleep onset latency and increased number of awakenings, accompanied by higher sleep fragmentation throughout the first night. An adaptation effect can then usually be seen in the second night (Agnew, Webb et al. 1966; Curcio, Ferrara et al. 2004; Sforza, Chapotot et al. 2008). To test for the presence of any first-night-effect in the present study's setting, measurements of the first and second night will be compared.

Below, several further expectations on the findings of the present study are stated. These, rather than being expressed as hypotheses, will be examined in order to assess the consistency of the present study with common chronobiological findings.

As former studies on adolescents could demonstrate repeatedly, students are on average anticipated to be later chronotypes than the remaining population (Wolfson and Carskadon 1998; Roenneberg, Kuehnle et al. 2004; Randler 2009). This finding is expected to be repeated in the present study.

Previous research showed up a strong relation between processed data yielded from MCTQ and sleep logs (Roenneberg, Kuehnle et al. 2007). Therefore, sleep log data and the results of the MCTQ assessed among adolescents are expected to show a significant correlation. At the same time, chronotypes and social jetlags of the participating students are expected to be consistent with those of the main MCTQ-database.

In the findings of Roenneberg et al. (2007) individuals with later chronotypes are less in phase with their internal clock when having to adhere to a schedule of getting up early. According to this, the later chronotypes among participating students in this study are expected to suffer from relatively higher social jetlags.

Another enquiry will be made into the question if the common observation, that total sleep throughout the week is less in late chronotypes than in early ones, will be observed among participating students.

2 Materials and Methods

2.1 Participants

34 healthy students (8 male) from different grammar schools in Germany volunteered to participate in this study. Their mean age was 17.04 years with a range from 14 to 19 years. Mean BMI was 20.82, with a standard deviation (stdev.) of 2.58.

Prior to participation, every student was thoroughly informed about the aims and procedure of the study. Those who were less than 18 years old had their parents signing an informed consent, while students older than 18 years signed by themselves (see appendixes 1 and 2). These consent forms also contained information about anonymisation of any personal data for further computation and use. For any published material displaying the participants, an approval form (see appendix 3) was signed by themselves, or respectively by their legal representatives, as well.

Most of the students went to school regularly during the test phase. However, three of them had holidays and one indicated every day as school day due to school-workshop-activities on the weekend.

For all participants, school usually started at 8 a.m. and ended approximately at 2:30 p.m. School-times were declared by all participating students as very inflexible. The duration of school days varied among participants.

2.1.1 Exclusion Criteria

Every participant was subjected to medical history taking and physical examination, in order to exclude those who had sleep disturbances, physical or mental diseases. A standard anamnesis sheet (see appendix 4) was used in order to detect any physical or mental pathologies. Examined were: head, eyes, mouth and fauces, cervical lymph nodes, thyroid gland, heart and lungs, abdomen, nervous system, skeletal system and skin. Inquiries were made about physical wellbeing, digestive function and micturition, allergies, medications, drug abuse and mental wellbeing. In addition, every student

was asked about the quality of his/her sleep. As recommended by Fricke-Oerkermann et al. (2007), special attention in recruiting participants was also drawn on excluding subjects with common diseases that might affect sleep, such as pathologies of the cardiovascular system and the respiratory tract, as well as those with pruritic skin diseases, like neurodermatitis. Further exclusion criteria were substance abuse, disturbed sleep, e.g. by bruxism, nightmares, sleep apnoea or snoring, and a BMI >25. Students with ADHD and those who took medications other than oral contraception were also excluded from the study.

Height and weight of students were recorded on percentile-sheets (see appendix 5).

In order to exclude depressive students, the WHO-5 questionnaire was used. This score aims to investigate wellbeing by assessing basic properties of subjective quality of life, like mood, vitality and interests ((Bech 2010) and appendix 6). For rating the score, each of the five questions is allocated on a 6-point Likert scale from 0 to 5, or respectively from "not present" to "present". As a result, raw scoring from 0 to 25 is possible, with higher scores standing for better wellbeing. Scoring less than 13 points is defined as being a hint to poor wellbeing. For such cases, further testing for depression is recommended. In this study, students with a score below 13 were excluded.

2.1.2 Ethical Approval

The ethics committee at the Department of Psychology, Ludwig-Maximilian-University (Munich), gave ethical approval for this study. Participants were informed about their right to end participation without any explanatory statement at any time. They were also informed about their data being coded so that data evaluation could occur on an anonymous basis. Since the accomplishment of the study was declared as a school-project, participating students were covered by school insurance.

2.2 Materials

2.2.1 Munich Chronotype Questionnaire (MCTQ)

This questionnaire (see appendix 7) aims at assessing individual sleep timing and phase of entrainment by asking simple questions about sleep-wake behaviour separately for workdays and free days (Roenneberg, Wirz-Justice et al. 2003; Roenneberg and Merrow 2007). Subjective statements are enquired, regarding time of going to bed, time to fall asleep, time of waking up and getting up, as well as use of an alarm clock. Furthermore age, sex, height and weight are inquired. The MCTQ facilitates an accurate quantification of the human phase of entrainment (Roenneberg and Merrow 2007). The exact parameters measured and calculated with the MCTQ are displayed under 2.3.2 ("Data Treatment").

Reliability and external validity of the MCTQ are high (Kuehnle 2006) as shown with repeated sleep log assessment. Actimetry measurements confirmed the validity of the MCTQ (Kantermann 2008). Mid-sleep on free days (MSF), as extracted from the MCTQ, also correlates highly with the Morningness-Eveningness-Qestionnaire (MEQ) (Zavada, Gordijn et al. 2005). The MCTQ exists in several languages, as well as in special versions for shift workers and for pupils (Juda 2010). The latter version, which was used in this case, contains an addition of questions about school start and end-times and about the flexibility of school times (see appendix 8). It also asks how and in which time frame students arrive at school, in order to add this information to an estimation of daily exposure to sunlight.

Answering the MCTQ takes approximately 5 to 10 minutes (Vetter 2010). It was filled in online under http://thewep.org/en/pupils_study.php .

2.2.2 Sleep Logs (SL)

Participants were instructed to fill in sleep logs daily every morning after getting up for a study period of two weeks.

The following items were extracted from the sleep logs: time spent outside during the prior day, bed-time, time of preparing for sleep, sleep latency, subjective alertness at bed-time (0 = very tired; 10 = very alert), wake-up time, time to get up, use of an alarm clock, subjective sleep quality (0 = slept very badly; 10 = slept very well), subjective alertness when waking up (0 = very tired; 10 = very alert), whether it was the morning of a work- or free day and personal annotations as to what factors might have influenced sleeping. Students were also asked to add the category "wellbeing" (WB) for the previous day, respectively (0 = feeling very bad; 10 = feeling very good).

Further parameters computed from the sleep log data are displayed in section 2.3.2 "Data Treatment").

The sleep logs were handed out to participants together with a detailed explanatory sheet (see appendix 9) about their usage. Furthermore, each student was explained by word of mouth, how to utilise the sleep log.

2.2.3 Zeo® – Advantages and Functions of a Simplified EEG

The application of an EEG and the respective visual scoring of the obtained data is a labour-intensive task which is reserved to be performed correctly by well-trained clinicians (Tran, Thuraisingham et al. 2009). According to Gold (2002) the advantages of polysomnography (PSG) are becoming scrutinised in Germany. Being based on the recording of a classical EEG, it is rather expensive and labour-intensive. Against the background of health-policies aiming at economising the health-system, the use of classical EEG appears not to have sufficient viability in many cases, as in the present study within its field setting.

Obviously it would be desirable to profit of an entire EEG-system that is both: easily applied and easy to be analysed. Anderson et al. (2010) expound the need for automated systems that could approximate these requirements, commenting that in clinical settings the need of using EEGs is often higher than the number of experts needed to read these. Throughout the past, several attempts have been made to create simpli-

fications of EEGs in usage and evaluation that can compete with insights obtained from visual scoring of the classical EEG.

A novel attempt of simplifying EEG has been forwarded with Zeo®, which appealed as an ideal tool in order to easily and cheaply record EEG-data in the field.

Five Zeos® from Zeo.Inc. in Newton, MA, USA were used in the present study. These consist of a headband with integrated sensors, which according to Zeo.Inc. (2010) wirelessly transmit EEG, EOG and EMG -signals to a base station for processing (Fabregas, J et al. 2009). Sleep stages are scored automatically by a neural network to phase sleep; as explained by Zeo. Inc. (2010). The Zeo® headband uses 3 silverised conductive, frontal sensors to collect electrical signals from the cortex. Since the electrical signals collected initially are typically only as small as 5-100 microvolts, they are then being amplified.

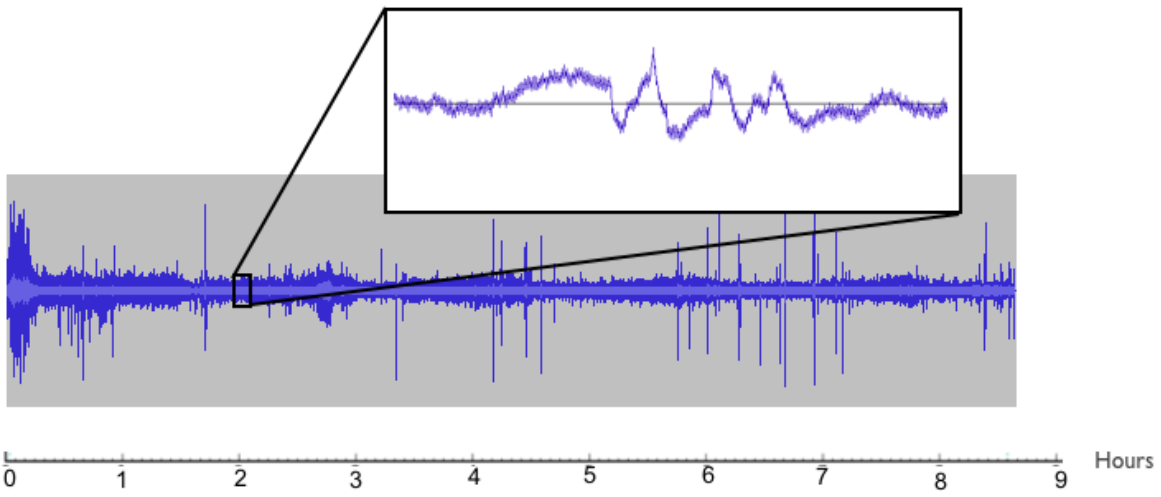

Figure 2.1: Signals being amplified – modified after Zeo.Inc (2009)

Then, specific individual 'features' that are associated with different phases of sleep are being extracted, using fast fourier transform as a signal-processing technique.

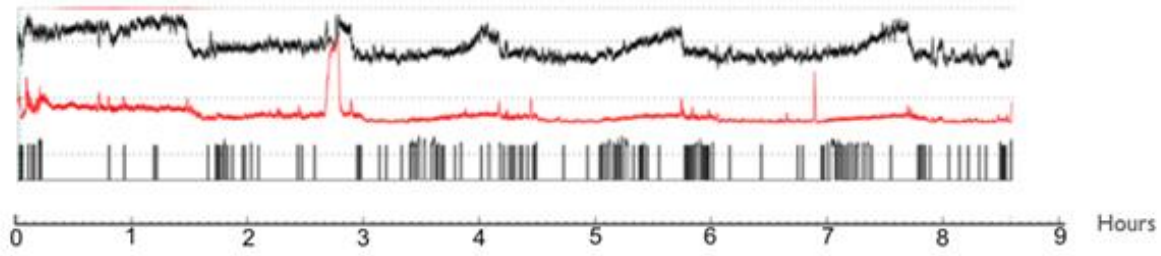

Figure 2.2: Sample features from amplified signals – modified after Zeo.Inc (2009)

After this step, according to Zeo (2010), artificial intelligence is being added, by comparing the signal 'features' from the last step to those usually seen in PSG. A neural network then estimates the probability that an individual is in a certain phase of sleep.

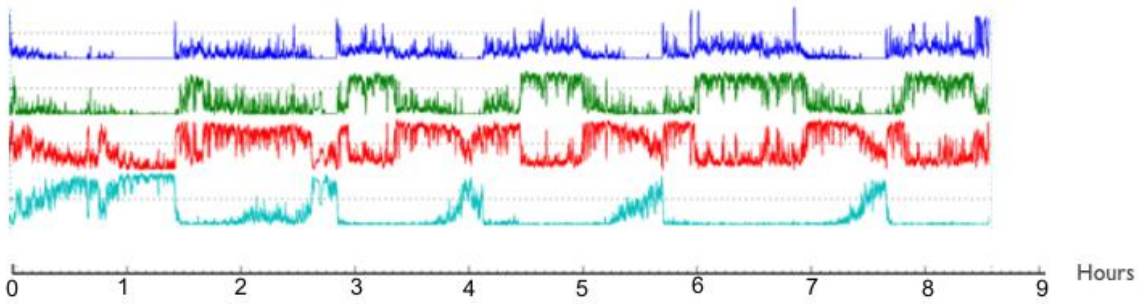

Figure 2.3: Zeo® neural network – probabilities of wake, REM, light or deep phases – modified after Zeo.Inc (2009)

The neural network codes a certain sleep phase every second of the night, but the sleep phases are being smoothed out and the results reported for every 30 sec. and five min. interval. Zeo.Inc. declare that all measured sleep parameters are being analysed according to the guidelines of Rechtschaffen and Kales (Blake, Pittman et al. 2009).

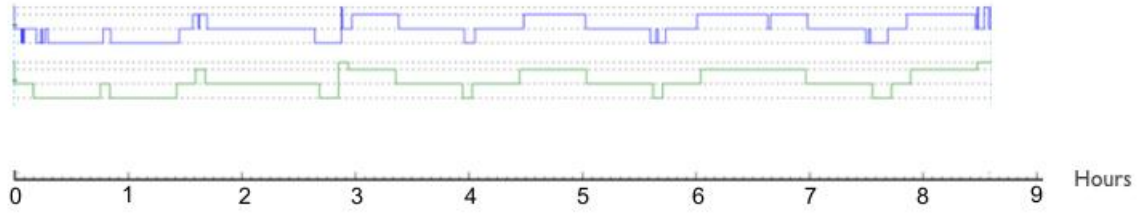

Figure 2.4: Sleep phases for 30 second (blue) and 5 minute intervals (green) – modified after Zeo.Inc. (2009)

Thus no raw data can be retrieved from Zeo®.

Zeo® was developed by a group of students at Brown University, Newton, Massachusetts. In an abstract, Shambroom et al. (2009) state to have compared it to the sleep stage measures derived from PSG that was manually scored following the guidelines of Rechtschaffen and Kales (1973) by two trained technicians blinded to the results of the wireless EEG. The results derived from the wireless system were alleged to be reasonably comparable to those derived from PSG (Shambroom, J et al. 2009). In a likewise study out of which only the abstract and a poster were available, Blake et al. (2009) found this wireless system to yield similar results as PSG, stating also that the device performed better on healthy volunteers than on sleep disordered subjects. Both Shambroom et al. (2009) and Blake et al. (2009) agree that the system shows promise as an easy to use method for measuring sleep stages related to sleep quality.

The parameters measured by Zeo® are listed as follows:

Zeo®-Parameter:	**Commentary:**
Total Sleep (TS):	A summation of Time in REM, Time in Light and Time in Deep. Since Zeo® appeared to perform an uprounding of any cipher behind the decimal point in ciphers resulting from this calculation, TS was corrected to being either downrounded in ciphers up to .49 or uprounded in ciphers onward from .5, according to DIN 1333 standards (Hackbusch, H.R. et al. 2003). The company's client contact did not reply when asked about further information regarding the rounding-algorithms via email. Thus for further calculations the corrected values were used. These differed by one minute in half of the cases and were the same for the other half group.
Time to Sleep (TTS):	Time between taking the headband off the base-station and falling asleep. Since students often put on the headbands

before actually turning off the lights, TTS was corrected, subtracting the time between putting on the headband and turning off the lights when in bed.

Time in Wake (TIW): Time spent awake during the night. This did not include TTS or time awake after the last sleep phase of the night.

Time in REM (TIR): Time spent in REM-sleep.

Time in Light (TIL): Time spent in sleep stages 1 and 2, which are centralised as light sleep.

Time in Deep (TID): Time spent in sleep stages 3 and 4, which are centralised as deep sleep.

Awakenings (Aw): Number of times a test-person woke up during the night, irrespective of the duration of the time spent awake.

Start of Night (SN): Date and time of day when taking the headband off the base-station to put it on. Zeo® rounds these values by five minutes.

End of Night (EN): Date and time of day when putting the headband back onto the base station after a night's sleep. In contrast to Start of Night and Rise Time, this measure displays the exact, un-rounded time.

Rise Time / Sleep End (SE): Date and time of day when waking up after the night's last sleep phase. These values are also rounded by five minutes.

Sleep Graph: Drawn from numbers between 0 and 4 in the downloadable excel-file. This graph averages the initial measurements of 30-second-intervals by five minutes. 0 = no measurement. This may occur when the headband is not in correct position on the forehead. 1 = awakeness, 2 = REM-sleep, 3 = light sleep and 4 = deep sleep. Individual sleep graphs are displayed on the password-coded part of Zeo's® website, turn-

ing numbers of sleep phases into bars.

Detailed Sleep Graph: Displays numbers as mentioned above, in 30-second-intervals throughout the night.

Sleep Date: Displays the date of start of night.

ZQ: This measure is suggested to measure sleep quality (Zeo 2010). It combines information about TS, restorative sleep and disrupted sleep, which stands for time spent awake and times woken up. Restorative sleep is defined by Zeo® as consisting of deep sleep and REM sleep. Since no valid studies could be found on this subject, ZQ was not paid any attention to in this work.

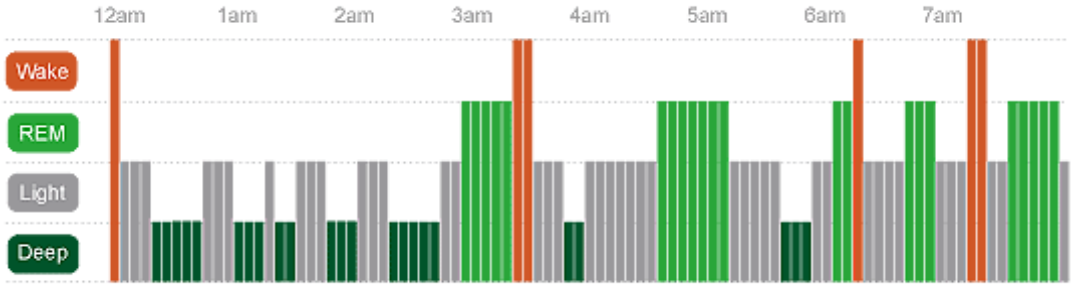

Figure 2.5: Sleep graph as displayed by Zeo®, displaying night-intervals of five minutes – source: Zeo.Inc. (2011)

Data received by the base-station of the wireless EEG can be uploaded via an SD-card in the base station that can be connected to a computer for uploading on www.myzeo®.org, from where it may be exported as an excel-file.

For reasons of copyright, Zeo.Inc. did not divulge the exact algorithms of data processing.

2.2.4 Software for Data Handling and Computation

All data were first entered into Excel 2004 for Mac, where initial data arrangement and computation were conducted. Statistical analyses were done with SPSS 10 for PC. Graphs and figures were drawn in Excel 2007 for PC.

2.3 Methods

2.3.1 Data Collection

The survey was conducted between June and August 2010.

An ambulance vehicle was reconverted into a mobile sleep laboratory. The so called "sleep mobile" contained four sleeping racks. Two beds were allocated above each other on each side of the vehicle's interior, respectively.

Figure 2.6: The sleep mobile: from outside and inside, with Zeo® base-stations

Initially, grammar schools throughout Germany were contacted via biology-teachers and school-psychologists. Whenever the headmaster gave his/her consent, lessons about chronobiology were held in biology- or psychology classes. In the end of such lessons, pupils were offered to participate in the present study. Informed consent sheets were given out to those aspiring to take part.

In the following part, students whose parents had signed the informed consent sheet (or who signed themselves, if over 18) were allowed by the headmaster to leave class

for 15 minutes for a personal meeting, including anamnesis and physical examination. They were also asked to fill out the MCTQ.

Subsequently, two consecutive nights of Zeo®-measurements in the sleep mobile followed for each participant. Each measuring occurred ahead of free days, in order to let the students sleep in, according to their physiological needs. The door of the sleep mobile made a lot of noise when closing or opening it, and there was fluctuation of the vehicle when people moved inside. Due to this, it was assumed that the adherence to entirely individual sleep-timing could not be met. Students of the same group of participants were thus allowed to go to sleep at the same time. Respectively up to four students of the same sex slept in the sleep mobile on two succeeding nights. The vehicle was parked on the schoolyard with bathroom facilities next to it. The study-conductor (St.B.) spent the night awake in a room immediately next to the sleep mobile, and was thus always addressable through an open window. The school-psychologist was also always approachable during the nights. Prior to measurement-nights, the local police was informed, their number saved and access to telephoning-facilities assured.

Participants were called into school at 8 p.m. They engaged in games and conversations held in quiet surroundings with slightly dimmed lights until becoming tired. The time of going to bed was optionally chosen. Zeo®-headbands were applied shortly before going to sleep in order for the participants to get used to wearing them. Time of "lights out" was recorded manually in order to correct Zeo®'s recording of "time to fall asleep" later on. The latter measurement was also limited, by students being allowed to talk "a little bit" when lying in bed.

In the mornings students were allowed to get up at individual times, although their timing was often similar due to unsteadiness of the vehicle and noise of the door whenever a person left it.

As an incentive and an acknowledgement to the students, each participant received an email with his/her personal sleep-profile after recording of the EEG, and they were bestowed with book-presents dealing with chronobiology and sleep.

Figure 2.7: Participants in the sleep mobile, wearing their EEG-headbands (foto with permission of students and their guardians)

2.3.2 Data Treatment

Time of day is being reported in decimal units i.e. one minute is broken down into 100 units instead of 60 seconds.

Basic Computation of Raw MCTQ-Data:

MCTQ-Data were computed to yield MSF_{sc} as a core parameter for this study, among others as shown below. The following calculations of the variables displayed below were identical for MCTQ and sleep logs. All parameters exist for free days (_f) and workdays (_w), apart from average sleep duration (ØSD). Below, MCTQ and Sleep Log variables are displayed, as proposed by Vetter (2010):

Obtained Parameters:

1) Bed Time (BT)

2) Sleep Latency (SL)

3) Sleep End (SE)

4) Use of Alarm Clock (A)

5) Sleep intertia (Sl_In)

Computed Parameters and their Algorithms:

1) Sleep Onset (SO): $BT + sleep\ latency\ (SL)$

2) Sleep Duration (SD): $SE - SO$

3) Mid-Sleep (MS): $SO + \frac{SD}{2}$

4) Average Sleep Duration (ØSD): $\frac{SD_w \cdot x_w + SD_f \cdot x_f}{x_w + x_f}$

* x_w = relative number of workdays / x_f = relative number of free days

5) MSF_{sc} /Chronotype: $\begin{cases} if\ SD_f > SD_w & \rightarrow \quad MSF - \frac{SD_f - \emptyset SD}{2} \\ if\ SD_f \leq SD_w & \rightarrow \quad MSF \end{cases}$

6) Social Jetlag (SJL): $|MSF - MSW|$ (Wittmann, Dinich et al. 2006)

Basic Computation of Raw Sleep-Log-Data:

Sleep logs were entered into Excel-files in order to calculate further parameters as explained for the MCTQ.

Test persons 16, 19 and 27 had only free days: in their cases MSF was used instead of MSF_{sc}. ID 22 was excluded from MSF- and ØSD-calculation because this student had no free days during sleep-log keeping.

ØSD was calculated in accordance with Roenneberg et al. (2004) and Frey et al. (2009) with the formula: $\frac{5 \cdot SD_w + 2 \cdot SD_f}{7}$. In case of IDs 16, 19 and 27, their mean SD_f was used as ØSD, instead of applying the named formula.

Basic Computation of Zeo®-Data:

Three cases (IDs 13.1, 30.1 and 32.2), in which the Zeo®-headband fell off during the night were excluded from measurements.

"Lights Out" (LO) was calculated as an additional parameter instead of the Zeo®-parameter "Start of Night" (SN) since the latter did not correspond to the given circumstances (see above). The manually recorded time spent outside bed with headband on was subtracted from SN. Like SN, LO was averaged by 5 minutes.

SO was calculated using the formula: SN + TTS. SO was then displayed before 0:00 0' clock with negative- and after 0:00 0' clock with positive ciphers.

"Sleep Duration (SD) from Sleep Onset to Rise Time" (SDSORT) was computed by calculating SE – SO. The attained value displays the duration of the complete individual night, including all arousal phases.

MS was calculated via the formula: $\frac{SO+SDSORT}{2}$.

Identifying REM-Phases (REMP) and Sleep Cycles (SC):

REM-occurrences and SC were counted visually per person and means were calculated. A SC was counted from one REMP to the next, with exception of the first cycle, which was counted from SO to first REMP, unless it began with a SOREM phase. A nights' last SC would thus end with the nights' last REMP. Two REMPs interrupted by a wake-phase would not be counted as a SC.

SOREMPs were also identified visually. According to the American Academy of Sleep Medicine (2001), any REMP that occurred within 10 minutes of sleep onset was defined as SOREM.

Numbers of REMP and of SC were transformed with z-scores. Then entries with > 2 stdev. were identified as outliers and excluded from further calculations. This was the case for IDs 12.1 and 28.1 for both nr. of REMP and SC. After this the count of REMP and SC was correlated with the appearance of SOREM (see Results).

Statistical Tests:

Prior to any statistical testing, ouliers were excluded, that exceeded 2 standart deviations from the mean. Statistical tests were always controlled for violation of the as-

sumption of normality of distribution. This was tested with the Kolmogorov-Smirnov-test which is recommended by Weiß (2008) for small sample sizes. Whenever violation of normality would occur, the corresponding tests would be applied – such as the Mann-Whitney-U-test, instead of students' T-test; as will be remarked in the respective cases. For continuous data correlation, the bivariate two-tailed correlation coefficient was calculated, whereas nominal and ordinal data were correlated using point-biserial, two-tailed correlation. Whenever no comment is stated on the applied kind of correlation, bivariate, two-tailed correlation was applied. The classification of correlation-results and effect sizes occurred according to the criteria of Buehner (2004). The level of significance at which hypotheses could be accepted was defined at .05.

Comparison of MCTQ/Sleep-Log-Data:

Whenever parameters such as "MSF_{sc}", derived from MCTQ or SL are not specified into "_MCTQ" or "_SL", MCTQ-data were used preferentially, whereas SL-data served only for filling in when students had completed the MCTQ inadequately. This was the case for IDs 7, 19 and 27. From IDs 15, 17 and 18, neither MCTQ nor SL could be obtained.

In accordance with Field (2005), effect sizes for t – values were calculated by the formula: $r = \sqrt{\frac{t^2}{t^2+df}}$.

Comparing Variance between Nights:

For the question of significant variances of differences between 1st and 2nd night, repeated measures analysis of variance (rANOVA)was performed with the Zeo®-data, using the covariates: MSF_{sc} & age (MSF from MCTQ, except for ID 7 of whom MSF from sleep log was used because no MCTQ entry could be obtained. IDs 9, 15, 17 and 18 could not be used for MSF correlation because no sleep log or MCTQ data were received). All tests of within-subject-effects resulted insignificant apart from TTS & respectively interaction between night-number and age in months. Considering these results, the decision was made to use both first and second night per student for further statistical means.

Correlation of MCTQ-, Sleep-Log- and EEG-Data:

In order to correlate data from MCTQ, Sleep-Log and Zeo®, median-values were taken from sleep logs, while means were used from MCTQ and Zeo®. The sleep logs were treated this way to minimise mavericks, as they were only kept for the short time of two weeks.

3 Results

3.1 Description of Obtained Data

3.1.1 List of Obtained Data

For an overview of obtained data, the table below shows the number of obtained sleep logs, MCTQs, and Zeo®-sleep profiles.

Item obtained	**Number**
Test-Persons	34
MCTQs	28
Sleep Logs	27
Zeo®-data: 2 nights complete	21
Zeo®-data: 2nd night complete or with minor losses	26
Zeo®-data: 2nd night complete	23
Zeo® -data: at least 1 night complete	7
Zeo®-data: 2 nights incomplete with minor data losses	3
Zeo®-data: only 1 night with temporary data loss	5
No Zeo®-data obtained	2

Table 3.1: number of obtained sleep logs, MCTQs, and Zeo®-sleep profiles

3.1.2 Zeo®-Measurements

Mean amounts of measured night phases in minutes and numbers of Aw, with stdev., minimal- and maximal values are displayed in the table below. Outliers were excluded beforehand.

	Mean	Stdev.	Minimum	Maximum
TS	470.87	73.77	311	605
TTS	17.45	14.01	1	58
TIW	13.09	17.37	0	68
TIR	141.70	47.22	41	238
TIL	229.71	45.20	137	324
TID	92.58	19.00	52	139
Aw	1.80	1.43	0	5

Table 3.2: mean amounts of night phases in min., and numbers of awakenings

Night-phase-percentages of total sleep-phase duration from sleep onset to rise time (SDSORT) are displayed in the following table:

Night Phase	% of SDSORT
TS	96.32
TIW	3.49
TIR	29.50
TIL	47.73
TID	19.06

Table 3.3: Night-Phase-Percentage of SDSORT

3.1.3 Further Parameters Calculated from Zeo®-Data

Other parameters computed from the Zeo®-output are listed below:

Zeo®-Parameter	Mean	Stdev
LO	0,24	0,83
SO	0.57	0.82
SDSORT	8.02	1.38
MS	4.58	0.79
RT	8.59	1.24

Table 3.4: further parameters computed from Zeo®-output

3.1.4 REM-Phases, Sleep Cyles and Appearance of Sleep-Onset-REM

Students had on average 6.28 REM-phases and 5.34 sleep cycles per night.

Surprisingly, sleep-onset-REM phases (SOREMP) were identified in nearly half of the participants. Five students had measurements of SOREM in the 1st night (two of whom

spent only one night in the sleep mobile, three showed SOREM only in the 2nd night and eleven showed SOREM in both nights. Given this unexpected observation, post-hoc hypotheses were generated, as elucidated in the discussion. Various correlations were then performed pertaining to SOREM, as pointed out detailed in 3.2.

3.2 Analysis of Obtained Data

3.2.1 Analysing Variance of Sleep-Parameters between the 1st and 2nd Night

Initially, first and second nights were compared, in order to test for a first-night effect and to evaluate the necessity to exclude the first night from further computation.

The following graph was drawn as a comparative depiction of total amounts of night phases in the first- and second night:

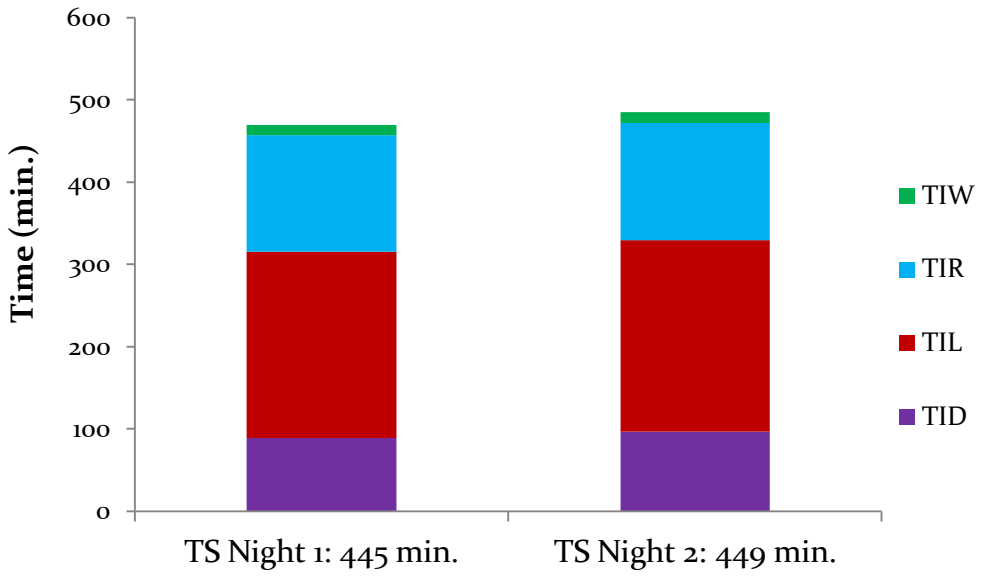

Figure 3.1: means of sleep phases during night 1 and 2 compared

A repeated-measures ANOVA (rANOVA) with the covariates MSF_{sc} and age in months was performed to examine the amount of variance between parameters measured in the 1st and 2nd night. All tests of within-subject-effects resulted insignificant apart from TTS and respectively the interaction between NightNr ($F(1.15) = 12.46$, $p < .05$). This effect was especially present considering the interaction between NightNr and age

($F(1.15) = 11.23$, $p < .05$). The mean of TTS was 4.14 min. longer in the 2nd night. However, it should be remarked that TTS is no confident parameter since test persons usually went to sleep at the same time. Although the usual expectation is that test-persons sleep better in the 2nd night due to the "first night effect" (Agnew, Webb et al. 1966; Curcio, Ferrara et al. 2004; Sforza, Chapotot et al. 2008), this result does not show any significant customization of the students between the 1st and 2nd night. For these reasons both nights were used when performing further computations. Mean times spent in the measured night phases, and results of rANOVA are displayed in the table below:

Comparing 1st and 2nd night				
	1st Night	**2nd Night**	**F**	**P**
TS	444.56 (17.09)	449.97 (18.06)	2.39	.142
TTS	**15.42 (2.34)**	**19.56 (3.00)**	**12.43**	**.003**
TIW	12.41 (2.80)	13.81 (3.88)	.94	.347
TIR	141.26 (9.61)	142.15 (8.45)	2.55	.130
TIL	227.07 (8.50)	232.67 (8.90)	.457	.510
TID	88.70 (3.64)	96.76 (3.48)	.510	.032
Aw	2 (0.23)	1.56(0.23)	.17	.682

Table 3.5: means and SEM (within parentheses), and rANOVA results of sleep variables during 1st and 2nd nights

3.2.2 Comparing MCTQ-Data with Sleep Log Data

Means and stdev. of those MCTQ- and sleep-log parameters of capital importance are opposed in the following table:

	MCTQs			**Sleep Logs**	
	Mean	**Stdev.**		**Mean**	**Stdev.**
MSF_{sc}	4.48	.62		4.53	.70
MSF	5.32	.63		4.87	.52
MSW	2.86	.63		3.17	.73
SD_f	9.19	.97		7.88	.86
SD_w	7.09	.92		7.14	.83
ØSD	7.84	.59		7.46	.83

Table 3.6: means and stdev. of important MCTQ- and sleep-log parameters

MSF_{sc}, MSF, MSW, SD_f, SD_w and øSD from MCTQs and Sleep logs were first subjected to bivariate, two-sided correlation and then compared in paired samples *t*-tests. Effect sizes r were calculated.

Correlation of MCTQ- and Sleep Log Data:

As can be seen in the following table, MSF_{sc} _MCTQ showed an intermediate correlation with MSF_{sc} _SL ($r = .420$, $p < .05$). Between the other mentioned parameters, no correlation could be found.

Parameter	N	r	p
MSF_{sc} _MCTQ & MSF_{sc} _SL	**24**	**.420**	**.041**
MSF_MCTQ & MSF_SL	22	.299	.177
MSW_MCTQ & SW_SL	23	.398	.060
SD_f_MCTQ & SDf_SL	24	-.122	.571
SD_w_MCTQ & SDw_SL	23	.256	.239
ØSD_MCTQ & ØSD_SL	23	-.026	.905

Table 3.7: correlations for paired samples between MCTQ and SL

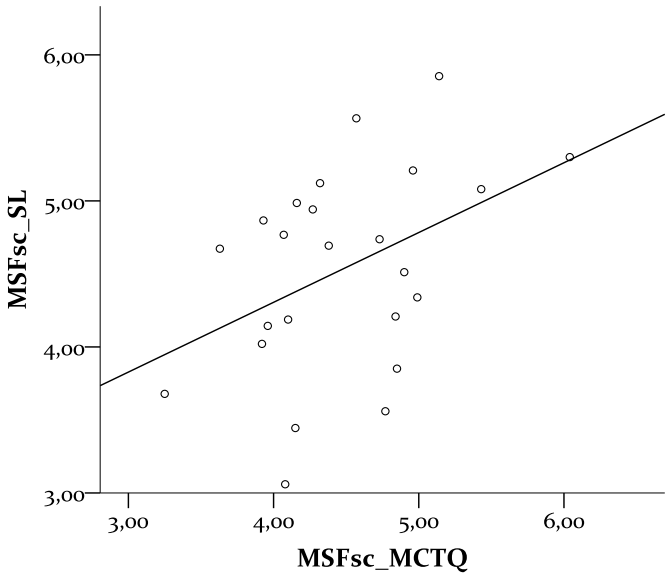

Figure 3.2: correlation between MSFsc _MCTQ and MSFsc _SL (R2 Linear =.177; N=24; r=.42; p=.041)

T-Test - Looking for Differences between MCTQ and Sleep Logs:

In order to augment results from correlations between MCTQ- and Sleep-Log-Samples, students T-test was performed, analysing for significant differences between the respective parameters.

Between MSF_{sc} _MCTQ (M = 4.48, SE = .13) and MSF_{sc} _SL (M = 4.53, SE = .14) no significant differences were observed (t (23) = -.389, p > .05).

Significant differences of intermediate effect size were shown in MSF between MCTQ (M = 5.32, SE = .13) and SL (M = 4.53, SE = .14, t (21) = 3.08, p < .05, r = .56), with MCTQs having measured higher values than SLs.

MSW was on average less in MCTQ- than in SL-data, although these differences between MCTQ (M = 2.86, SE = .13) and SL (M = 3.17, SE = .15, t (22) = -1.963, p > .05) were not significant.

SD_f was significantly longer in MCTQ (M = 9.19, SE = .20) than in SL (M = 7.87, SE = .18, t (23) = 4.67, p < .001, r = .697), with a strong effect size.

The t-test showed no significant difference between SD_w of MCTQ (M = 7.10, SE = .19) and SL (M = 7.14, SE = .17, t (22) = -.185, p > .05).

øSD had no significant difference between MCTQ (M = 7.84, SE = .12) and SL (M = 7.46, SE = .17, t (22) = 1.739, p < .05).

The above results are displayed in the table below.

	Mean	**Stdev**	**SEM**	**T**	**p**
MSF_{sc} _MCTQ & MSF_{sc} _SL	-.057	.71	.15	-.389	.701
MSF_MCTQ & MSF_SL	**.45**	**.69**	**.15**	**3.077**	**.006**
MSW_MCTQ & MSW_SL	-.31	.75	.16	-1.963	.062
SD_f_MCTQ & SDf_SL	**1.31**	**1.38**	**.28**	**4.665**	**.000**
SD_w_MCTQ & SDw_SL	-.04	1.07	.22	-.185	.855
ØSD_MCTQ & øSD_SL	.38	1.04	.22	1.739	.096

Table 3.8: paired samples T-test between MCTQ and SL

3.2.3 Comparing MCTQ–Database-Distributions with those of the Present Study

Initially, MSF from this population's sample was compared to MSF from entries of all 14-19 year olds in the main MCTQ-database. To do so, the correction of MSF, MSF_{sasc} was used in order to compensate for the different distributions of 14 to 19 year olds and of males and females in both samples.

	MCTQ Database	Present Study
N	6948	29
mean	4.46	4.48
mode	3.07	4.01
median	4.53	4.51
variance	2.61	0.83
stdev	1.62	0.91
SEM	0.02	0.17

Table 3.9: comparison of MSF_{sasc} in main database and present study

No statistical analysis was performed to compare MCTQ-Data from the main database (N = 6947) with those of the present study, due to the incompatibility of sample sizes.

Out of interest, SJL was also compared between means of 14- to 19 year-olds in MCTQ-database and of the present study, although no correction for sex and age exists for SJL. Considering the incompatibility of both groups due to different distributions in age, which is a variable indirectly influencing SJL (Roenneberg, Wirz-Justice et al. 2003), the table below is to be regarded as nothing more than an approximative tool of comparison.

	MCTQ Database	Present Study
N	6906	29
mean	2.63	2.28
mode	18.00	2.54
median	3.50	2.46
variance	1.60	1.12
stdev	1.27	1.06
SEM	0.02	0.20

Table 3.10: comparison of SJL in main database and present study

3.2.4 Correlation of Chronotype and Social Jetlag

An intermediate correlation was shown between MSF_{sc} and SJL (r = .505, p = .016).

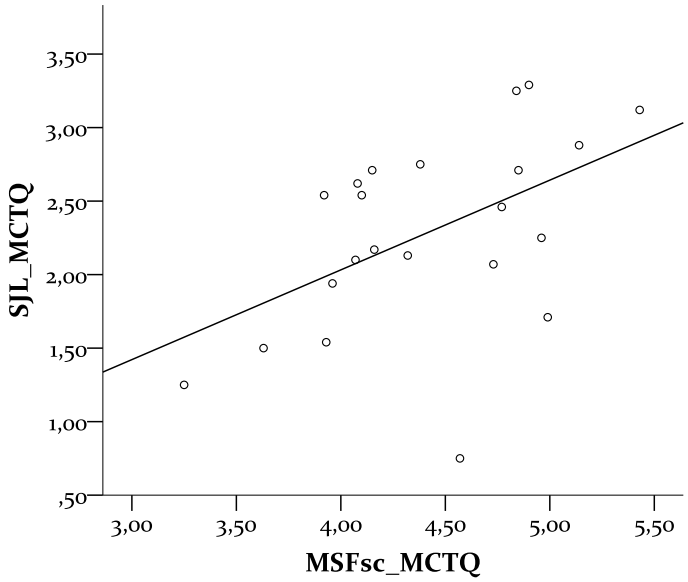

Figure 3.3: correlation of MSF_{sc} with SJL (R^2 Linear =.255; N=22; r=.505; p=.016)

3.2.5 Relation between MSF_{sc} and øSD

In order to examine the relation between MSF_{sc} and ØSD, these variables were also subjected to correlation. To do so, MCTQ- and sleep log-data were used, respectively.

A weak, negative correlation was shown between the MCTQs' MSF_{sc} and øSD (r = -.392, p < .01).This negative correlation also showed up with a medium effect size between MSF_{sc} and øSD of sleep logs. (r = -.553, p < .001). Hence on average, the later the student's MSF was, the less time they would spend sleeping over-all.

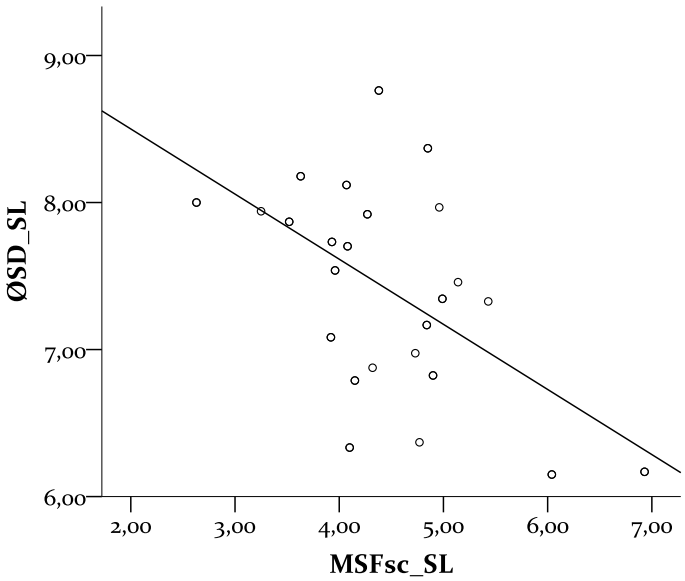

Figure 3.4: correlation of MSF_{sc} and øSD from SL, (R^2 Linear=.305; N=43; r=-.553; p=.000)

MSF_{sc} was then subjected to correlation with SD_f and SD_w. An intermediate negative correlation was seen between MSF_{sc} and SD_f (r = -.452, p = .03), while there was no significant effect between MSF_{sc} and SD_w (r = -.363, p = .097).

The following graph depicts the relation between sleep duration on school- and free days with MSF_{sc}. It shows the longer sleep duration on free days as compared to week days. The regression line is seen to decline less steeply on free days than on workdays, with increasing lateness of chronotype.

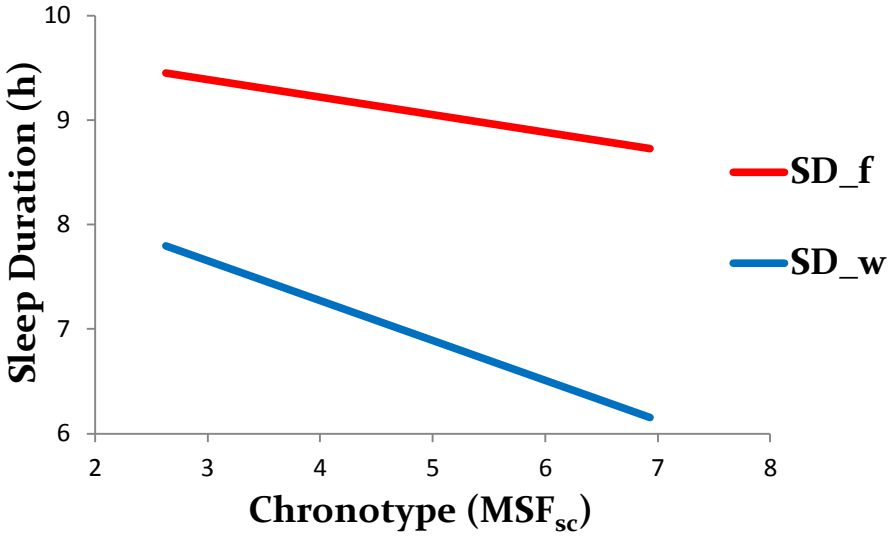

Figure 3.5: comparison of sleep duration on free- and schooldays, in relation to MSF_{sc} (see data above)

3.2.6 Relations between MSF_{sc} and Zeo®-Parameters

No significant correlation could be shown between MSF_{sc} and the Zeo®-parameters displayed in the table below.

Zeo®-Parameter	r	p
TS	-.219	.144
TTS	-.115	.455
TIW	-.014	.927
TIR	-.104	.492
TIL	-.269	.077
TID	-.216	.155
Aw	.097	.522

Table 3.11: correlations of Zeo®-parameters with MSF_{sc}

MSF_{sc} was then divided at the median value of 4.5 into an earlier-and a later chronotype group. These groups were then again examined for pointbiserial correlations with the Zeo®-parameters: SO, Nr. of REMP, Nr. of SC, TS, TTS, TIW, TIR, TIL, TID, and Aw. No significant correlations between the named parameters were found, as shown below.

Parameter	**r**	**p**
SO	.265	.099
Nr. of REMP	-.258	.103
Nr. of SC	-.195	.221
TS	-.158	.352
TTS	-.042	.800
TIW	.005	.974
TIR	-.055	.730
TIL	-.231	.152
TID	-.064	.694
Aw	-.155	.332

Table 3.12: pointbiserial correlation between earlier-and later chronotype-group, and Zeo®-parameters

In order to test for differences in distribution of sleep parameters among the two chronotype categories, a **Mann-Whitney-U-Test** was performed. This test was chosen instead of students' T-test to account for the categorical scaling of chronotype in two divisions. Zeo® parameters tested for difference between chronotype categories were TS, TTS, TIW, TIR, TIL, TID and Aw. None of these sleep parameters differed significantly between the two chronotype categories. Test statistics are displayed below:

	MSF_{sc} < **4.5; Median**	**MSF > 4.5; Median**	**U**	**p**
TS	504 min.	475 min.	163.00	.475
TTS	15 min.	15 min.	168.50	.988
TIW	7 min.	8 min.	183.00	.745
TIR	149 min.	150 min.	201.00	.969
TIL	232 min.	218 min.	134.50	.178
TID	88 min.	99 min.	179.50	.943
Aw	2	2	160.50	.338

Table 3.13: Mann-Whitney-U-Statistics of chronotype in 2 categories and Zeo®-parameters

Beyond testing for relations between MSF_{sc} and initial Zeo®-Parameters, MSF_{sc} was also examined for correlations with several Zeo®-derived parameters. This occurred, performing pointbiserial correlation, since these parameters were categorical variables. MSF_{sc} showed no relation with the appearance of SOREM, nr. of REMP and SC (see table below).

	r	p
SOREM	-.187	.203
Nr. of REMP	-.217	.148
SC	-.258	.084

Table 3.14: pointbiserial correlation of MSF_{sc} with SOREM, nr. of REMPs and SCs

3.2.7 Relations among Zeo®-Parameters

Correlating Zeo®-parameters among each other, significant positive effects were observed between TS and TIR ($r = .471$, $p < .001$ – medium effect), and between TS and TIL ($r = .316$, $p < .05$ – weak effect).

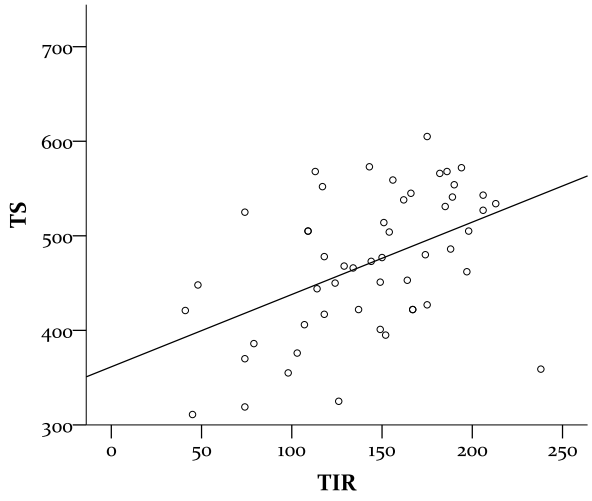

Figure 3.6: correlation of total sleep and time in REM (R^2 Linear=.222; N=52; r=.471; p=.000)

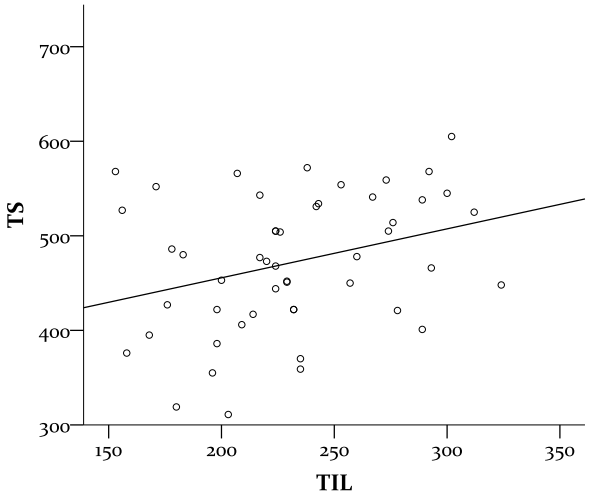

Figure 3.7: correlation of total sleep and time in light sleep (R^2 Linear=.1; N=50; r=.316; p=.025)

A weak negative correlation was found between TIW and TIR (r = -.368, p <.01), which may imply that the less wakefulness was measured, the more REM would be measured; possibly instead of wakefulness.

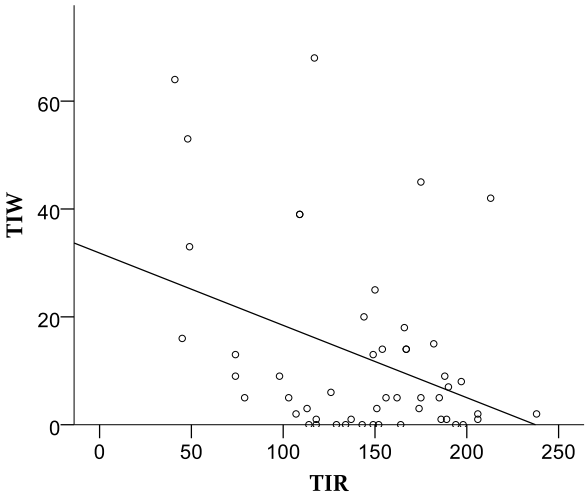

Figure 3.8: correlation of time in wake and time in REM (R^2 Linear=.136; N=51; r=-.368; p=.008)

This finding will be explored further in the discussion since it is suspected that the latter outcome may be due to faulty discrimination of Zeo® between states of wakefulness and REM.

As one would suspect there was also a positive correlation between TIW and Aw (r = .507, p < .001 – medium effect).

The above correlations are summarised in the table below:

	MSF_{sc}	**TScor**	**TTScor**	**TIW**	**TIR**	**TIL**	**TID**	**Aw**
TScor					**P****	**P***		
TTScor								
TIW					**N****			**P****
TIR		**P****		**N****				
TIL		**P***						
Aw				**P****				

Table 3.15: bivariate, 2-sided correlations of Zeo®-parameters
P = positive correlation, N = negative correlation, empty field = no correlation
*Significance level of .05
** Significance level of .01

3.2.8 Correlation of Sleep Onset and Sleep End between MCTQ and Zeo®

A weak, positive correlation was found between SO_MCTQ and SO_Zeo® (r = .339, p = .028).

SE_MCTQ and SE_Zeo® showed no correlation (r = .054, p = .728).

The relation between ØSO and ØSE measured by Zeo® and MSF_{sc} from MCTQ in the first- and SL in the second place is depicted on the graphic below. A circular 24-h-diagram was drawn, displaying an MCTQ/SL-derived sleep window (blue), which was calculated by the formulas: ØSO = $ØMSF_{sc}$ – ½ ØSD and ØSE = $ØMSF_{sc}$ + ½ ØSD. Zeo®-derived SO- and SE-measurements were then also averaged and the range of their Stdevs (red) set into the corresponding time-frame. The depiction shows that Zeo®-measurements roughly met MCTQ-/SL-measurements, although only SO_MCTQ and SO_Zeo® showed a correlation.

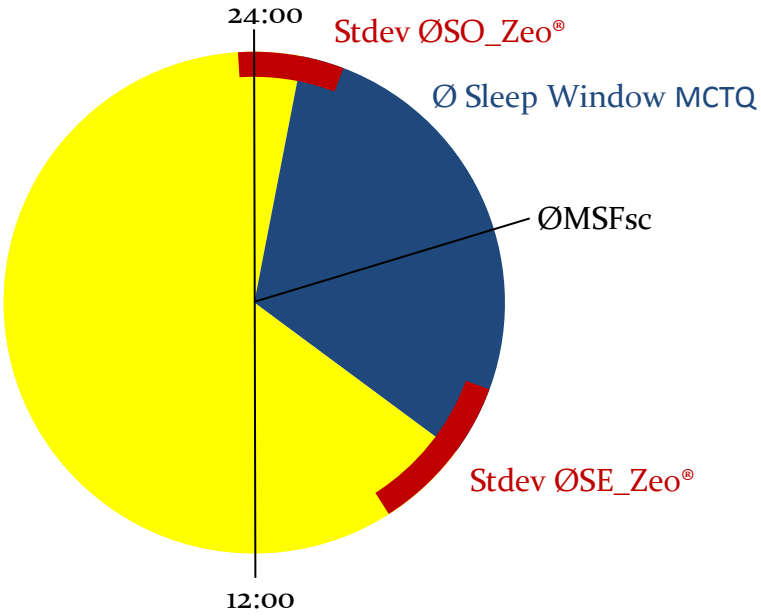

Figure 3.9: stdev. of ØSO and ØSE measured by Zeo®, in relation to MCTQ-derived ø sleep window on a 24-h-scale

3.2.9 Post-Hoc Hypotheses: A Challenge of SOREM

As mentioned in chapter 3.4, several post-hoc hypotheses were generated upon the frequent finding of sleep-onset-REM among the participating students. These were as follows:

- **Post-hoc hypothesis A:** Students with SOREM may have shown this alteration of normal sleep due to an overall sleep deficiency.
- **Post-hoc hypothesis B:** Zeo® may at times be confounding REM sleep with being awake.

These post-hoc hypotheses will be pointed out in detail in the discussion.

No pointbiserial correlation was found, neither between SOREM and median WB per person, nor between SOREM and Social Jetlag.

	r	p
WB	.297	.105
SJL	.115	.469

Table 3.16: pointbiserial correlation of SOREM with wellbeing and social jetlag

In search of correlations between SOREM and sleep-time discrepancy between workdays and free days, two procedures were applied: at first the general appearance of SOREM per student on one or two nights was correlated with w_f_discrepancy. Secondly every night, with- and without SOREM (irrespective of student) was correlated with w_f_discrepancy. W_f_discrepancy was calculated by subtracting SD_w from SD_f. No significant correlation was found in either of both proceedings ($p > .05$).

After this, another pointbiserial correlation of SOREM with the measured Zeo®-parameters was performed, as can be seen on the table below. A positive, small sized correlation between SOREM and TS was shown. Another positive, small sized correlation was found between SOREM and TIR.

	r	p
TS	**.278**	**.044**
TTS	-.096	.501
TIW	-.157	.262
TIR	**.365**	**.007**
TIL	-.215	.131
TID	-.086	.545
Aw	-.240	.084

Table 3.17: pointbiserial correlation of SOREM with Zeo®-parameters

These two findings imply that individuals with SOREM may on average have had longer TS and more TIR than those without, if the measurement of SOREM was correct. However, this correlation may as well be regarded as a hint to Zeo® confounding wakefulness with REM-sleep. See the discussion for further comments on this issue.

A weak positive correlation was also shown between SOREM and the number of REMPs ($r = .373$, $p < .01$). Thus the more SOREM was measured the more REMPs were identified. No correlation was found between SOREM and the number of SCs ($p > .05$).

	r	**p**
Nr. of REMP	**.373**	**.006**
Nr. of SC	.101	.470

Table 3.18: pointbiserial correlation of SOREM with nr. of REMP and nr. of sleep cycles

Since SOREM-phases showed no correlation with neither MSF_{sc} nor SJL, WB or sleep-time discrepancy between work days and free days (see Results part two) and for reasons specified in the discussion, it was suspected that these measurement may have occurred due to poor discrimination of Zeo® between wakefulness and stage 1 sleep.

4 Discussion

I'm not asleep... but that doesn't mean I'm awake.

Author Unknown (2011)

The present study aimed at evaluating a field setting for the exploration of adolescents' chronotype and sleep phases. It had a pioneering approach in being the first study to use a mobile sleep lab in which the sleep of adolescents was measured at school, via the automated EEG-system Zeo®.

The offer of participating on a night spent with friends, sleeping in the sleep mobile was readily accepted by a sufficient number of students. Zeo® proved to state an easily used tool; however, unfortunately Zeo®-measurements turned out to have a considerable probability of being partly inaccurate when measuring REM phases, as will be pointed out below. No relation between chronotype and sleep phases could be detected in this study. Keeping in mind the circumstances of measurements being partly unsatisfactory, these results may be subjected to re-questioning in following studies.

4.1 Students' Chronotypes

Initially chronotypes of the participating students were identified, using the MCTQ. The mean chronotype among participants was 4.48, which is consistent with the average general chronotype (Roenneberg, Kuehnle et al. 2007). This finding was confirmed by the correlation that was seen between chronotype-variables of MCTQs and sleep logs. A typical effect of "lateness" that was expected among the adolescents in opposition to the general population might have been more obvious if the students had been on average 3 years older, since 20 year olds are known to be the latest chronotypes (Roenneberg, Kuehnle et al. 2004). Another reason for the average chronotype to be

intermediate rather than late in the present study is the size of the sample group. In a larger group instead, such an effect would usually have been observed.

Another expectation that was assumed previously to the present study predicted a positive correlation between chronotype-values of MCTQs and sleep logs, as this correlation has been demonstrated thoroughly. In contrast to findings of Kühnle et al.(2006) a significant correlation between MCTQs and sleep logs could be shown only for MSF_{sc}. No correlations were found among the other parameters measured by MCTQ and sleep logs. This is believed to have occurred due to inadequate filling in of sleep logs, as will be pointed out in "Strengths and Weaknesses of this Study". It is expected that if sleep-log keeping could be optimised, the correlations between sleep-log- and MCTQ-variables would be higher.

4.2 Chronotype and Social Jetlag

Students' chronotypes showed an intermediate correlation with their social jetlags. This fact is consistent with Roenneberg el al's (2007) finding, that among individuals who follow a similarly early schedule of getting up, those with later chronotypes will be less in line with their internal phase. Later chronotypes will therefore have a higher social jetlag. Adding up to this, the relation between chronotype and average sleep duration was examined. It was seen that generally, the later students' chronotypes were, the less time they would spend sleeping on the average night. Sleep duration was longer on free days than on school days and always decreased with increasing chronotype. These effects underline the impact social time schedules have on students, when these schedules are not in line with their physiological needs.

4.3 The First Night Effect

When variances of Zeo® parameters between nights were compared in repeated measures ANOVA, no first night effect was detected. There was no significant variance

among sleep-parameters between the first and second night, with an exception of the time needed to fall asleep. This parameter was on average 4.14 min. longer in the second night. Such a finding is unusual when compared with studies examining the first night effect. The common finding in polysomnography would be a decrease in sleep latency rather than an increase (Agnew, Webb et al. 1966; Curcio, Ferrara et al. 2004; Sforza, Chapotot et al. 2008). One may argue that this increase may have been a result of the students having a greater sleep deficit on Friday night, following a week of getting up early, as compared to Saturday night, when they had already caught up on this deficit. One may also speculate that students might have been more relaxed in the second night, being more accustomed to the experimental setting, so that they had a tendency to talk more than in the first night. Anyhow, this finding may as well have occurred merely by chance, especially since the small size of the test-group would have rendered it more vulnerable to such a mistake.

The usual standard in sleep labs is to exclude the first night's data from further examination (Gold 2002). This is due to the common consideration that the first night is one in which the subject has to get used to the artificial surroundings in the sleep lab. Nevertheless, it should be kept in mind that the mobile sleep lab setting is not comparable with being subjected to the rather artificially appearing surroundings in real polysomnography. Most students seemed to enjoy the night in the sleep mobile as a kind of "adventure" – possibly comparable to sleeping in a camp or at a friend's house, so that they may not have slept as badly as it is known from first nights in real sleep labs. In the present study thus, since it had few participants and ANOVA did not reveal any major variance between nights, the further use of both nights for evaluation was considered to be justified.

4.4 Night Phases, Compared to other Studies

The participating students were found to have spent 3.49% of their total sleep-phase after sleep onset awake, 29.5% in REM sleep, 47.73% in light sleep and 19.06% in deep sleep. For convenience, the values of the present study are compared to those of other studies in the two tables below. It has to be remarked that this comparison is limited

since age groups tested in the four studies named below are dissimilar to the present one.

	Present Study	Jenni and Carskadon (2004)	Tarokh et al. (2010)
Age	14 - 19	11 - 13	11 - 13
Total Sleep	470.87	540.2	563
Time in Wake	13.09	31.1	12.5
REM Sleep	141.7	100.4	112.5
Light Sleep	229.71	158.55	290
Deep Sleep	92.58	61.4	159.5

Table 4.1: night phases in minutes: present study compared to other studies

	Present Study	Carskadon et al.(1998)	Montgomery-Downs et al. (2006)
Age	14 - 19	14 - 16	6 - 8
Time in Wake%	3.49	3.49	8.1
REM Sleep%	29.5	17.5-19.5	19.6
Light Sleep%	47.73	63.5-62.2	46.8
Deep Sleep%	19.06	18.7-18.2	22.6

Table 4.2: night phases in %: present study compared to other studies

4.5 Sleep Mobile Sleep Timing in Relation to Real Life Sleep Timing

In order to compare the timing of sleep in the sleep mobile and that evaluated from the MCTQ, sleep onset and sleep end as measured by Zeo® were compared to a circular sleep window that was calculated from MCTQ data. The earlier half of this sleep window was defined as a subtraction of ½ of the average sleep duration from MSF_{sc}, and the later half as an addition of ½ of the average sleep duration to MSF_{sc}, as displayed in the graphic on p.52. The graphic showed that sleep onset and sleep end in the sleep-mobile night matched on average those defined by the circular sleep window. Nevertheless, a significant correlation could only be demonstrated between sleep onset in the measuring night and from MCTQ data, whereas sleep end was not found to be related between both. Although the exact reasons for this remain unclear, it can be rea-

soned that the disturbances in the sleep mobile upon the getting up of the first of four students were too strong to allow physiological "sleeping in" of more than one person at a time.

4.6 Sleep-Phases In Relation to Chronotype and in Relation to Each Other

In order to elicit the influence of chronotype on the durations of sleep phases, the parameters total sleep, time to sleep, time in wake, time in REM-, light-, deep sleep and awakenings were tested for correlations with the chronotype and with each other. No correlation was shown between chronotype and any of the named parameters; neither when using MSF_{sc} as a metrical variable in bivariate correlation, nor when dividing it into an older and a younger chronotype group in pointbiserial correlation. There were also no significant differences seen when performing a Mann-Whitney-U-test.

Hypothesis 1 predicted that later chronotypes would be observed to fall asleep later in the sleep mobile, than earlier ones. Contrasting this hypothesis no correlation between chronotype and sleep latency was detected. This is believed to be a consequence of a) the study setting in which students were allowed to go to sleep by four persons at a time, and b) two effects countering each other: on the one hand, later chronotypes are well known to go to bed later than their peers (Roenneberg, Kuehnle et al. 2007). On the other hand, the later types would be expected to have a higher sleep pressure than the earlier types, when having similarly early getting-up schedules. These two effects may equal each other out. In a larger group, effects may well have been observable if they were not countering each other with the same strength. **Hypothesis 1** thus has to be refuted since it has been shown that the applied setting lacks individual opportunities of sleep-timing, thereby enlarging the risk of falsifying outcomes in sleep latency.

Hypothesis 2 stated that later chronotypes should have been observed to spend more time sleeping in the sleep mobile overall than earlier types, due to the greater sleep deficiency they developed throughout the preceding school-week. Since no such effect could be observed within the applied setting, it is believed that the same argument

applies for this question, as for hypothesis 1: the overall setting lacked individuality in the election of sleep-timing. This especially applies for being allowed to go to sleep at the same time as the other three students of the respective group and the sleep mobile moving and making noise whenever the door would be opened, which are factors that lead to a falsification of a commonly well-known picture. Thus **hypothesis 2** has to be refuted as well.

4.7 Correlations among Sleep Phases

Correlating Zeo®-parameters with each other, a significant relationship was found between the total duration of sleep and times spent in REM- and light sleep. This relation may well have been expected, being founded on the common observation that the second half of sleep consists basically of light sleep and REM sleep (Borbely 1984; Payne and Nadel 2004; Carskadon and Dement 2005).

However, an unexpected negative correlation was seen between time in wake and time in REM, implying either that the less time students would be awake, the more time they would spend in REM, or that Zeo® may have overestimated REM-sleep. The latter thesis is favoured in this case because, as will be pointed out below, there is a considerable possibility for a frontal EEG of confounding the awake state with REM sleep. The named observation is not properly supportable by the common literature. For this reason, post-hoc hypotheses were generated and tested, as will be pointed out below.

4.8 Problems Measuring REM Sleep – Post Hoc Hypotheses

A perfection of means, and confusion *of aims, seems to be our main problem.*

Albert Einstein (1879-1955)

For the present study, an easy to use and inexpensive means was sought in order to measure EEG, instead of applying classical EEGs. Indeed, Zeo® proved to fulfil the

named requirements, yet unfortunately it also proved to miss the aim of yielding fully reliable measurements, as will be pointed out.

After surprisingly among 19 out of 32 participants, sleep onset REM (SOREM) was measured overnight, two **Post-hoc hypotheses** were added to the previous ones. SOREM is usually known to appear in subjects who suffer from depression or other psychological illnesses as well as in narcoleptics and in those who are severely sleep deprived (AASM and Medicine 2001). Singh et al. (2006) investigated the appearance of SOREM among the common population in Detroit/USA among 539 subjects. They examined several variables for any influence on the appearance of this phenomenon, finding that the only measure that appeared to be significantly associated with it was an objectively excessive sleepiness, as measured by the multiple sleep latency test, which is commonly applied to objectify sleepiness (Sullivan and Kushida 2008). They conclude that "therefore, subpopulations with excessive sleepiness (e.g. shift workers, young adults, patients with apnoea) are likely to have a greater prevalence of SOREMPs." In succession to the findings of Singh et al. (2006), the primary post hoc assumption is that those students who revealed an appearance of SOREM in their Zeo® measurements, being otherwise healthy, may have shown this alteration of what is known as "normal sleep" due to an overall sleep deficiency **(post-hoc hypothesis A)**. Grounding this hypothesis, it was suspected that MSF_{sc} may be correlated with appearance of SOREM because sleep-deprived individuals (& thus later chronotypes) tend to have more SOREM. This was not the case. There was also thought to be a negative correlation between SOREM and wellbeing if SOREM occurred due to an accumulated sleep deficiency. However, as stated above, wellbeing was filled in unsatisfactorily in sleep logs, so that this query-item could not be evaluated properly. SOREM was further on assumed to correlate positively with social jetlag, as an increased misalignment with internal phase is expected to lead to an increased REM-pressure upon falling asleep. This assumption was made because SOREM is known to appear more frequently in sleep deprived individuals (Shaikh, Patel et al. 2010), who in turn may be sleep deprived as a consequence of being later chronotypes and suffering from an increased social jetlag. Due to a lack of studies on the phenomenon of SOREM in relation to chronotype, the expectation of SOREM to increase with increased social jetlag is one that cannot be justified perfectly. No relation between chronotype and SOREM was

found which may have been due to the overall physical and mental health of students, who may have compensated their social jetlags well, not showing any signs of phase disalignment. There are currently no studies available on the subject of SOREM and social jetlag, so that argumentation on this question remains hypothetical. In order to test more precisely for an expected relation between increased sleep deficit and increased appearance of SOREM, this phenomenon was also subjected to correlation with sleep discrepancy between schooldays & free days. If post-hoc hypothesis A was true, individuals with SOREM would be expected to have higher sleep discrepancies between school- and free days than those without, because they would have to recuperate on a higher sleep deficiency. In statistical analysis, no such relation was seen between SOREM and sleep discrepancy. Since all tests failed to support **post-hoc hypothesis A**, it has to be refuted. Notwithstanding, one may still consider the possibility that SOREM, rather than being a sign of any pathological or sleep deficiency-process as it is known from adults, may be a physiological phenomenon in adolescents. Bishop et al. (1996) found SOREM to appear in 23% out of 139 healthy young adults. Mignot el al. (2006) detected SOREM in 7% among 556 test persons who were not narcoleptic. Nevertheless, both studies examined adults and the affected subjects tended to be young males, which reduces the possibility of comparison with the present study in which females predominated. Carskadon et al. (1998) discovered high rates of SOREM in adolescents. This was especially the case after their school start times had been advanced between 9th and 10th grade from 8:25 to 7:20. Whereas in 9th grade, 4 of 32 subjects manifested SOREM, this rate rose up to 12 of 25 in 10th grade. They therefore conclude that the appearance of SOREM is closely linked to increased sleep deprivation which is caused by the advance of school start time. It has to be emphasised that all three studies mentioned above mainly investigated the occurrence of SOREM in the Multiple Sleep Latency Test (MSLT). This test is performed in daytime, as an objective measure of physiological sleepiness. Individuals are encouraged to sleep several times per day, having their sleep latencies evaluated along with standard EEG (Sullivan and Kushida 2008). Unfortunately no studies exist as to the incidence of SOREM in the night-sleep of healthy adolescents. Tarokh et al. (2010), who performed all-night PSG in young adolescents do not refer to any occurrence of SOREM in their measurements. Carskadon and Jenni (2004) compared all-night PSG-measured be-

tween children and young adolescents and did not report any cases of SOREM. Other polysomnography studies that have been performed on children have neither found increased incidences of SOREM (Coble, Kupfer et al. 1984; Montgomery-Downs, Hawley et al. 2006). Summing up the observations in the studies named above, although there is a possibility of SOREM to appear in healthy young individuals, it is rather unlikely that this would occur as frequently as it did in the present study.

Opposing post-hoc hypothesis A, another possibility explaining the frequent appearance of SOREM in sleep profiles is that Zeo® may at times be confounding REM sleep with being awake (**post-hoc hypothesis B**). General considerations in support of this assumption are pointed out in the chapter below.

4.9 Several Reasons for the Assumption that Zeo® Overestimates REM

4.9.1 General Considerations on Measuring REM with Automated- and Classical EEGs

It is well known that raw EEG-data in REM sleep tend to appear similar to those measured in awake subjects (Zschocke 2002). However, using standard EEG, there are several ways of distinguishing these states. As such, it is the occipital electrodes of the classical EEG that best measure α-waves and are thus the best locations to discriminate between wakefulness and stage 1 sleep (Zschocke 2002). A common sign of tiredness are slow eye movements. Slow eye movements are occasionally also seen in tired individuals with closed eyes. These movements disappear upon the entrance into stage 1. Such eye movements could be confused by Zeo® with rapid eye movements. In combination with the non-specific EEG signals they may support mistaking sleepy-but-awake-states with REM. This becomes obvious, considering that fast frontal beta-activity may be measured in awake subjects, as well as in stage 1 and in REM sleep. Zschocke (2002) highlights that in automated analyses of EEG there is a heightened chance of confounding the named states. He draws the conclusion that „In order to attain a complete overview on the electroencephalographic sleep organisation, an ap-

plication of electrodes from the frontopolar to the occipital region is indispensable." In accordance with Zschocke, Gelisse and Crespel (2008) could demonstrate in a polysomnography study that individuals show similar rhythms in REM sleep as when awake or merely drowsy. This similarity is focussed on a high alpha output during REM, as well as in quiet rest with closed eyes.

A system similar to Zeo®, called QUISI® also works with three sensor electrodes placed on the forehead. It was evaluated by Ehlert et al. (1998) against standard polysomnography. In their evaluation, Ehlert et al. state that: "While sleep period time, total sleep and sleep onset latency showed high correlations, REM and slow wave sleep were generally overestimated." Both, REM-and slow wave overestimation may have occurred partly as a consequence of lacking occipital derivations, in which alpha and delta waves can be measured best (Zschocke 2002). Ehlert et al. (1998) reason that their findings may be a consequence of eye movements in awake stages during the night. These phases, particularly when combined with low muscle potentials may be falsely recognized as REM. Later studies performed by Gfullner and Siemon (2000) and Fischer et al. (2008) agreed that although QUISI® supplied a basic impression of sleep architecture, it was not able to replace common PSG, lacking its accuracy.

Another example of an automated EEG-system is the bispectral index (BIS®). Originally developed to measure the depth of anaesthesia during surgery, this frontal EEG was also tested for its ability to evaluate sleep stages. Like Zeo®, it is combined with EOG and EMG. Raw data of BIS® are automatically transcribed into an index, reaching from 0 to 100 – the higher the count, the more alert the individual. Two studies (Sleigh, Andrzejowski et al. 1999; Nieuwenhuijs, Coleman et al. 2002) had to conclude, that although BIS® was worthwhile at approximately estimating depth of sleep, it could not accurately classify sleep stages. Especially between REM-sleep and the awake state, a considerable overlap was seen.

Ehlert et al. (1998) cite Herrmann and Kubicki (1984), who compared seven different automated systems of sleep-analysis with PSG. All but one system used EOG and EMG in addition to four EEG-channels. Herrmann and Kubicki's (1984) findings are stated to have shown that five of seven systems overestimated the amount of SWS, while two underestimated it. REM-sleep was overestimated by all seven systems. Awakeness was

calculated only by six of the seven systems, out of which four over– and two underestimated awakeness. In addition to these findings, Ehlert et al. (1998) state that most of the literature they reviewed "showed an overestimation of REM stage and of slow wave sleep if automatic analysis methods were compared with visual analysis according to Rechtschaffen and Kales."

Since Zeo.Inc. do not specify the mechanisms underlying the discrimination between REM-sleep and awakeness, it is assumed that similar properties as in other automated EEGs may lead to similar faults in measurement. Although its mere measures of frontal EEG derivations may well be correct, the simple fact that an EEG has to be derived from several cortical regions in order to be properly evaluated explains the insufficiency of frontal derivations in the accurate evaluation of sleep stages. Most importantly occipital electrodes are needed in order to complete the analysis of sleep profiles.

4.9.2 Specific Evidence for Zeo's® Overestimation of REM

Examining the influence of the measured Zeo®-parameters with each other, a significant negative correlation between time in wake and time in REM was found. This finding would imply that the longer students were awake the less REM would be measured, or in other words that whenever they woke up they would have been deprived from REM-sleep, which was rather surprising. Although there is a slight tendency in younger adolescents to wake up out of REM-sleep (Akerstedt, Billiard et al. 2002), it is implausible that this fact would lead to a general decline of REM sleep in those who woke up from this stage. Therefore it is suspected that this finding may be due to faulty discrimination of Zeo® between states of wakefulness and REM. This suspicion is undermined by the fact that Zeo® measured sleep onset REM-phases in nearly half of the students, despite any correlation of these phases with social jetlag or with the discrepancy between sleep duration on school days and sleep duration on free days.

Another improbability is that there would have been a positive correlation between SOREM and the duration of total sleep. This correlation may rather be regarded as a hint to Zeo® confounding wakefulness with REM-sleep.

On their website (http://www.myZeo®.com/pages/52_for_health_professionals.cfm), Zeo.Inc. publish several abstracts of studies performed on Zeo®. Yet unfortunately there is no link available to any full-text-papers. The studies are listed below:

- Wright K, Johnstone J, Fabregas SE, Shambroom JR. Evaluation of a Portable, Dry Sensor-Based Automatic Sleep Monitoring System. Sleep. 2008;31
- Wright K, Johnstone J, Fabregas SE, Shambroom JR. Assessment of Dry Head-band Technology forAutomatic Sleep Monitoring. Journal of Sleep Research. 2008
- Fabregas SE, Johnstone J, Shambroom JR. Performance of a Wireless Dry Sensor System in Automatically Monitoring Sleep and Wakefulness. Sleep. 2009;32
- Shambroom JR, Johnstone J, Fabregas SE. Evaluation of a Portable Monitor for Sleep Staging. Sleep. 2009;32
- Blake SK, Pittman SD, MacDonald MM, et al. Assessment of a wireless dry sensor to detect sleep in healthy volunteers and subjects with sleep disorders. Sleep. 2009;32

According to Zeo® (Fabregas 2011), these studies were all reported as abstracts at meetings of the Associated Professional Sleep Societies and the European Sleep Research Society. Zeo® claims to have been working on a full manuscript for submission, which, however, has not yet been published.

In March 2011, after acquisition and evaluation of data for the present study had been finished, Prof. T. Roenneberg had a personal communication at a congress with the president of Zeo.Inc., D.P. Dickinson. Mr. Dickinson is reported to have stated that "Zeo® never evaluated the amount of REM-sleep adequately" (Roenneberg 2011).

For all reasons named above, **post-hoc hypothesis B**, stating that Zeo® tends to confound the awake state with REM sleep is being adopted.

4.10 Strengths & Weaknesses of this Study

The present study succeeded well in testing a procedure to examine the sleep of adolescents in a field setting; yet the applied procedure has been shown to yield unsatisfactory results. As a major factor, unfortunately the obtained Zeo®-measurements proved to be too inaccurate to provide a reliable foundation for scientific research. Having known earlier the rather suspicious fact that Zeo.Inc. had not published their full-text results of testing Zeo® against polysomnography, one should primarily have indulged in this approach before applying this tool in the field. It is strongly suggested to perform serious comparisons of Zeo® against standard PSG before conducting any further inquiries about sleep architecture with Zeo®. Special attendance should then be paid to the amount and timing of REM sleep.

Vetter (2010) writes one chapter on the general assessment of chronotype in field studies. She addresses several criteria that may restrict the outcomes of such studies. The first priority among these is given to the compliance of participants. For the present study, aiming at yielding objective measurements by Zeo® to be compared with subjective measurements from MCTQ and sleep logs, compliance is regarded as being on the same priority level as accurateness of measuring instruments. Vetter (2010) suggests that interventions should be minimised in order to serve compliance. This is of special importance since field studies like the present one deal with relatively small sample sizes in which dropouts cannot be replaced easily. It is generally thought that this study did not exceed requests to the participants. However, there may still be ways of minimising the effort requested by them, as will be pointed out below. Vetter (2010) remarks that: “Exact replications of such studies are not possible.” Keeping this in mind, ways should be sought, to yield results as accurate as practicable.

A generally positive aspect of this study was that adolescents were overall very interested in the subject of sleep and chronotype, although sleep log keeping appeared to be perceived as a burden by many of them. Consequentially the sleep logs appeared to be a possible source of error. Most students had to be reminded numerous times to return their sleep logs. Reminding showed to have a higher efficiency whenever it occurred via the internet then via different communication pathways. Personal commu-

nication with the parents of several participating students revealed that often sleep logs would not be filled in as required. This became especially obvious in the subject of rating their wellbeing. This query-item was not among the questions listed on the questionnaire and thus students were asked to fill it in themselves – the compliance in filling in this variable was regarded too low to use it for further computations (N = 19). Such incompliance may be prevented in future studies, applying more effort initially e.g. by establishing the possibility to fill in sleep logs online, having a direct possibility of controlling the date and time of day on which they were filled in. Simultaneously, students could then be reminded automatically, whenever they would forget to fill in their sleep logs. One possibility that may be thought of, stating an incentive of compliance at the same time, would be I-phones, given out to participants that might fulfil this task (Roenneberg 2011). Obviously such proceeding would be more labour- and cost expensive. However, sleep logs would be more reliable. A simpler enhancement on this subject might also be to give out special prices to those who would return their sleep logs within the appropriate time-frame.

The fact that students were generally allowed to choose their own times of going to sleep was considered favourable. Nevertheless, this advantage was narrowed by the fact that four students were going to sleep at the same time. Future studies on sleep should always aim at allowing subjects to sleep throughout their personal sleep window; since e.g. sending a late chronotype to bed at 10 pm and waking them up at 6 am would definitely not reveal what may be termed as physiological sleep.

The timing and relation of sleep phases in relation to each other within the individual sleep architecture could theoretically have been examined as well in addition to examining the summative duration of sleep phases. However, this would have involved highly complicated analyses, using “regular expressions”, which would have exceeded the scope of this thesis.

4.11 Follow-Up Perspectives for this Study

In studies to follow, it would be preferable to obtain raw EEG data, rather than those already evaluated. In this way, more insights into details within the sleep-EEG of adolescents could be made. Although this would certainly involve more effort, this effort would be worthwhile as it would yield data of considerably higher quality.

Since overall the sleep-mobile setting was received well by participants, further studies in a similar setting may be planned. As a proposal to begin with, the present study could be iterated engaging in the sensible effort of applying classical EEGs. Further on, a similar study could investigate the differences in parameters measured in the present study between subjects in school time and in mid-to end-vacation time. An alternative to this may also be to compare students who go to school at 8:00 o'clock with others who begin school regularly on a later schedule. Shifting the emphasis to a rather medical point of view, it is also conceivable to test only subjects with certain diseases, such as ADHD.

Feinberg and Campbell (2010), as well as Tarokh and Carskadon (2010) recommend that more research into adolescent sleep should be performed in order to deepen understanding of the changes taking place in the adolescent brain. They suggest that such research could best be carried out in the adolescents' homes with easy to use EEGs. Obviously a Zeo®-like technique would be a good means for this in order to optimise compliance and to permit a normal sleeping environment. However, this should not occur unless there is valid proof for such a system of being comparable to PSG.

4.12 Conclusions

The setting of measuring student's sleep profiles in school on weekends within the sleep mobile was accepted well by the students and can be recommended for further research. However, knowledge to be gained out of Zeo® measurements is rather limited, especially since no raw data may be obtained. The mere apportionment of sleep into light sleep, REM sleep, deep sleep and awakeness does not provide enough in-

sights, especially when examining the sleep of special subgroups among students like those suffering from ADHD or from drug abuse. In these cases more detailed data would be of interest. Thus the use of classical EEGs would be favourable. This may be done in the same setting as in the present study. The use of classical EEGs would be more time-consuming in applying-, as well as interpreting them; however, results obtained would be of far higher quality with more details and thus providing a more profound basis for new insights.

Even though Zeo® is not seen as recommendable for serious research, it may well serve for use in health prevention programs, where it could be applied for being used by students in order to gain insights into their own sleep architecture, thus supporting awareness of sleep as an existential subject that deserves to attain high attention.

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7 Deutsche Zusammenfassung

Es ist allgemein bekannt und durch Studien belegt, dass Adoleszenten die Altersgruppe mit dem spätesten Chronotyp in der Gesellschaft darstellen. Sie gehen physiologischerweise später schlafen und stehen später auf, als die meisten Menschen anderer Altersgruppen. Gleichzeitig stellen Adoleszenten die Altersgruppe dar, welche die meiste Zeit mit Lernen verbringt, um sich (in der Schule) auf das spätere (Berufs-) Leben vorzubereiten. Da die von den meisten Schulen in Deutschland eingeforderten Zeiten des Schulbeginns um 8:00 Uhr eher denen früherer Chronotypen entsprechen, gehören Adoleszenten neben Schichtarbeitern zu der Altersgruppe mit dem höchsten Schlafmangel.

Es ist inzwischen anerkannt, dass gesunder Schlaf sowohl eine (der gesunden Ernährung und dem Sport ebenbürtige) Säule der Gesundheit und des Wohlbefindens darstellt, als auch eine entscheidende Rolle in der Konsolidierung von Gedächtnisinhalten spielt. Deshalb erscheint es wünschenswert, das Schlafverhalten von Jugendlichen zu optimieren. Hieraus ergibt sich als Konsequenz, dass die Zusammenhänge zwischen Chronotyp und Schlaf bestmöglich verstanden werden sollten, um neue Erkenntnisse zur Gestaltung von Gesundheitspräventionsprogrammen – speziell an Schulen - heranzuziehen.

Das Ziel war, einen weiterführenden Baustein für derartige Forschung darzustellen. In einem explorativen Ansatz sollte eine Methode untersucht werden, mit welcher der Schlaf "im wirklichen Leben", in einer Feldstudie untersucht werden könnte. Hierzu sollte eine einfache und kostengünstige Weise getestet werden, um Hypnogramme von Schülern in einem mobilen Schlaflabor ("Schlafmobil") unmittelbar in ihren Schulen zu ermitteln. Das mobile, automatisierte und leicht anwendbare EEG-System Zeo® erschien diesem Anspruch gerecht zu werden. Kabellos und mithilfe eines mit drei frontalen Elektroden versehenen Stirnbandes wertet dieses System unmittelbar die folgenden Schlafparameter aus: Gesamtschlafdauer, Schlaflatenz, Wach-Zeit nach dem Ein-

schlafen, Leichtschlaf (Statium 1 + 2), Tiefschlaf (Stadium 3 + 4) und REM-Schlaf. Somit müssen rohe EEG-Daten nicht mehr manuell ausgewertet werden.

Nach Erhalt der Hypnogramme wurden deren Daten mit den Chronotypen der Schüler korreliert. Hierzu erfolgte eine Untersuchung der genannten Schlaf-Parameter auf ihre Gesamtdauer in Relation zum Chronotyp. Außerdem wurden jw. die Gesamtdauern der Schlafphasen während einer Nacht miteinander korreliert. Vor Ableitung des Schlafprofils an jeweils zwei aufeinanderfolgenden Nächten pro Schüler wurde jeweils anhand des Münchener Chronotyp-Fragebogens der Chronotyp des Probanden ermittelt. Um diesen zu validieren und einen Einblick in das Schlafverhalten des jeweiligen Probanden während der Testphase zu gewinnen, wurden für jw. 14 T. Schlaftagbücher geführt.

Die Hauptfragestellung war, ob grundlegende chronobiologische Erkenntnisse über Schlafzeiten und –Phasen im Rahmen dieses Studiensettings mithilfe der Zeos® wie erwartet reproduzierbar wären.

Ein normalerweise in Schlaflaboren beobachteter First-Night-Effect konnte in einer Gegenüberstellung beider Nächte durch eine Messwiederholungs ANOVA nicht dargestellt werden, so dass für weitere Untersuchungen die erste und zweite Nacht herangezogen wurde.

Die erste Erwartung, dass spätere Chronotypen in genanntem Versuchsaufbau später einschlafen und aufwachen würden, als frühere Chronotypen, ließ sich nicht bestätigen. Auch die zweite Erwartung, dass spätere Chronotypen aufgrund eines erhöhten, unter der Schulwoche angesammelten Schlafdefizits einen längeren Gesamtschlaf aufweisen würden, um dieses Defizit aufzuholen, wurde nicht beobachtet. Beide Ergebnisse könnten Auswirkungen des Versuchsaufbaus sein, in welchem jeweils vier Schüler zur gleichen Zeit im Schlafmobil übernachteten, so dass es einem Schüler kaum möglich war, aufzustehen- oder schlafen zu gehen, ohne dabei die anderen zu wecken.

Es wurde keine Korrelation zwischen dem Chronotyp und der Gesamtlänge der genannten Schlafparameter beobachtet. Schlafbeginn und –Ende wurden mit einem aus dem MCTQ und Schlaftagebüchern errechneten zirkulären 24-h-Schlaffenster abgeglichen. Während der mit Zeo® gemessene Einschlafzeitpunkt mit dem Errechneten kor-

relierte, konnte keine Korrelation zwischen gemessenem und errechnetem Aufwachzeitpunkt aufgezeigt werden.

Eine unerwartete Auffälligkeit bei mehr als der Hälfte der Hypnogramme war, dass Schüler mit einer REM-Phase einzuschlafen schienen, statt erwartungsgemäß mit einer Leichtschlafphase. Unter der Testung der Gesamtlängen der einzelnen Schlafphasen auf Korrelationen untereinander zeigten sich folgende Ergebnisse:

- Die Gesamtschlafdauer korrelierte positiv mit der Leichtschlaf-Dauer.
- Die Gesamtschlafdauer korrelierte positiv mit der REM-Dauer.
- Die Wach-Zeit nach dem Einschlafen korrelierte negativ mit der REM-Dauer.

Auch die letztere Feststellung war unerwartet, da nicht davon ausgegangen werden konnte, dass nächtliche Aufwachphasen zu einer Verminderung des REM-Schlafes führen sollten. Aufgrund der unerwarteten Beobachtungen bezüglich des REM-Schlafes wurde die **Post-Hoc-Hypothese** entwickelt, nach welcher Zeo® dazu neigt, Wachstadien und REM zu verwechseln. Dies erschien nach weiterer Literaturrecherche sehr wahrscheinlich, zumal 1) der im EEG frontal gemessene REM-Schlaf dem Wach-Stadium sehr ähnelt, und alpha-Wellen, die dem entspannten Wachstadium mit geschlossenen Augen entsprechen, am besten dorsal abgeleitet werden können. 2) sämtliche Studien, nach denen Zeo® hoch mit herkömmlicher Polysomnographie korreliere, nur als Abstracts existieren und bisher nicht veröffentlicht wurden. Zudem wurden gegen Ende dieser Studie mündliche Mitteilungen von Zeo® bekannt, nach denen die Hardware der Geräte keine perfekte Beurteilung von REM-Phasen gewährleisten könne.

Schlussfolgernd kann festgestellt werden, dass der angewendete Studienaufbau des Erstellens von persönlichen Schlafprofilen bei Übernachtung im Schlafmobil grundsätzlich gut von den Schülern angenommen wurde und somit für nachfolgende Studien empfohlen werden kann. Eine Einschränkung diesbezüglich betrifft die Auswertung der Gesamtschlafdauer, bzw. des Einschlaf- und des Aufwachzeitpunktes, welche durch das gemeinsame Schlafengehen und Aufstehen ent-individualisiert werden. Von der weiteren Benutzung von Zeo® im Rahmen wissenschaftlicher Studien muss dahingegen abgeraten werden. Sinnvoll erscheint die Wiederholung dieser Studie mit klassi-

schen EEGs. Obwohl diese im Vergleich zu Zeo® eine erhebliche Erhöhung des Arbeitsaufwandes durch Anbringen und manuelle Auswertung mit sich ziehen würden, wäre dennoch simultan die Verlässlichkeit der Daten wesentlich erhöht. Zudem wäre eine größere Datenmenge erhältlich, da die rohen, unausgewerteten Daten eine Grundlage für eine verfeinerte Prüfung darstellen würden. Indessen kann Zeo® als ein durchaus verwendbares Gerät zur Schlaferziehung in Gesundheitspräventionsprogrammen betrachtet werden, in denen es weniger darum geht, verlässliche Daten zu erhalten, und mehr, auf einfache Weise den Blick auf den eigenen Schlaf, seine Struktur und seine Wichtigkeit zu schärfen.

8 Abstract of the Present Thesis

As it is commonly known and confirmed by several studies, adolescence is the time in life that goes along with being the latest chronotype in community. This implies that physiologically adolescents tend to go to sleep later and get up later than other age groups. At the same time adolescents are the age group who spend the highest amount of time studying (at school), in order to prepare for their later (working) life. Since the usually requested school start times in Germany around 8:00 a.m. rather meet the needs of earlier chronotypes than those of normal- and later ones, adolescents and shift workers belong to the groups with the largest sleep deficit.

There is a recognition that healthy sleep (adjacent to healthy nutrition and physical exercise) states one pillar of health and wellbeing, as well as playing a role in the consolidation of memory. For this reason it appears worthwhile to aim at optimising sleep behaviour and –circumstances in adolescents. Consequently the relations between chronotype and sleep should be understood, in order to gain new insights for the conductance of health prevention programs; especially in schools. The **aim** was to create one building block for such research. Thus the present study aspired to finding a method of examining the sleep of adolescents "in real life" via a field study with a mainly explorative approach. In order to do so, a simple and cost-effective method was sought, to obtain hypnograms of students in a mobile sleep lab at their school. The mobile, automated and easy to use EEG "Zeo®" was elected since it appeared to be an ideal tool for meeting the requests of the present study. This device consists of a headband with three frontal electrodes and a base station that records, inter alia, the following sleep parameters: total sleep, sleep latency, time awake after falling asleep, light sleep (stage 1 and 2), deep sleep (stage 3 and 4) and REM sleep. These are interpreted automatically so that no more manual evaluation of raw EEG-data has to be performed.

After hypnograms were obtained, their data were assessed in relation with the students' chronotypes. To do so, the total duration of the respective named sleep parameters were correlated with the chronotypes. Total durations of the respective sleep phases were also correlated with each other. Prior to deducing EEGs on two consecu-

tive nights per student, the chronotype of each participant was determined via the Munich Chronotype Questionnaire. In order to validate the obtained data and gain further insights into the individual sleeping-behaviour of participants, these were asked to fill in sleep logs for two weeks during the test-phase.

The **main question** of this thesis was weather common chronobiological expectations about sleep timing and –phases could be replicated in the sleep-mobile-setting, using Zeo®.

In opposition to the usual observance in sleep-labs, no first night effect was seen between the first- and second nights in repeated measures ANOVA. For this reason both nights were used for further analysis in this study.

The first hypothesis was that later chronotypes would be observed to fall asleep later in the sleep mobile, and wake up later. This hypothesis could not be confirmed. Similarly the second hypothesis, which expected later chronotypes to be observed to spend more time overall sleeping in the sleep mobile than earlier types, because they would have to catch up on their accumulated sleep deficit throughout the week, could not be approved. Both outcomes may be influenced by the study's set-up in which respectively four students slept in the sleep mobile at the same time. Thus there hardly was a possibility for one student to get up or go to sleep without waking up the others.

No correlation was seen between chronotype and the total duration of the above named sleep parameters. Sleep onset and sleep end were compared to an MCTQ- and sleep-log-deduced 24-h-sleep window. While sleep onset, as measured by Zeo® was correlated with the calculated value, no such correlation could be shown between calculated- and measured values for sleep end.

An unexpected finding in half of the hypnograms was that students were observed to have fallen asleep via a REM-phase rather than via a light sleep phase, as usual. Testing for correlations between the total durations of sleep phases, the following observations were made:

Total sleep showed a positive correlation with light sleep.

Total sleep showed a positive correlation with REM sleep.

Time awake after falling asleep showed a negative correlation with REM sleep

The latter discovery was unexpected, since there is no explanation as to why wake-up phases throughout the night might lead to a decline in REM-sleep. Due to the named unexpected findings regarding REM sleep, a post-hoc hypothesis was generated. This hypothesis assumes that Zeo® tends to confound wakefulness with states of REM. Further literature research showed a high probability of this hypothesis being correct, since 1) the frontal EEG-deductions during REM-sleep are rather similar to those deducted during wakefulness, whereas alpha-waves that can be observed in relaxed, awake test-persons with closed eyes are ideally deducted in the dorsal regions of the head. 2) all studies in which Zeo's® output is claimed to have a high correlation with classical polysomnography exist only as abstracts and have not yet been published completely. Furthermore, towards the end of the present study, oral communication with Zeo® approved that the device's hardware could not facilitate a perfect evaluation of REM-phases.

In retrospection the setting of measuring student's sleep profiles in school on weekends within the sleep mobile was accepted well by students and can be recommended for further research. A limitation in this regard is the analysis of total sleep, sleep onset and sleep end that are being de-individualised by the collective residence of students in the sleep mobile. A further use of Zeo® for scientific purposes cannot be advised, while a repetition of the present study with classical EEGs is regarded to be commendable. Although such proceeding would include a higher workload in applying and manually evaluating EEGs, the reliability of data would be considerably higher.

Moreover, the raw, unevaluated data that would be obtained could be used for a refined evaluation. In the meantime Zeo® may well serve for use in health care programs, where it could be applied for individuals to gain insights into their own sleep, its structure and importance.

9 Appendices

9.1 Consent Form for Students Younger than 18 Years

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München, Mai 2008

Lieber Schüler, liebe Schülerin,

Forscher des Instituts für medizinische Psychologie der Ludwig-Maximilians-Universität München – medizinische Fakultät – würden dich gerne im Rahmen einer Studie zum Schlafverhalten von Jugendlichen zu zwei aufeinander folgenden Übernachtungen im Schlafmobil „Eule" einladen. Es handelt sich bei diesem Projekt um die Studie, die bereits ausführlich im Rahmen des Biologie-Unterrichts vorgestellt wurde. Hierbei wurde auch erklärt, was Chronobiologie ist und wie die Rhythmen verschiedener Lebewesen untersucht werden. Das Ziel bei dieser Studie ist, mehr über den Schlaf von gesunden Jugendlichen zu erfahren. Wie bereits in der Vorbereitungsstunde erwähnt wurde, existieren bislang noch keine Schlafprofile von Jugendlichen in Deutschland.
Die Übernachtungen finden jeweils unter Aufsicht am Wochenende, auf dem Schulhof deiner Schule statt, wo das Schlafmobil dann aufgestellt wird. Es werden EEGs abgeleitet, um u.a. zu beobachten, wann du einschläfst und wie deine Schlafphasen aussehen. 10 Tage vor- und 10 Tage nach der Übernachtungsphase soll ein Schlaftagebuch geführt werden. Vor der Schlafmessung wird eine kurze Befragung, inklusive einer online-Befragung mit körperlicher Untersuchung stattfinden.
Die Teilname ist FREIWILLIG und du kannst jederzeit ohne Begründung deine Teilnahme an der Studie abbrechen. Die im Rahmen dieser Studie von uns erhobenen Daten werden selbstverständlich vertraulich behandelt. Das bedeutet, dass nur Prof. Roenneberg und Stephanie Böhm die Ergebnisse deiner Messungen anschauen dürfen. Solltest du dich entschließen, nicht mehr mitzumachen, werden deine Daten vernichtet. Wenn die Studie beendet ist, werden alle persönlichen Daten von dir vernichtet und wir behalten nur verschlüsselte Daten. Aus diesen kann dann niemand mehr erkennen, zu welcher Person sie gehören.
Bei Fragen kannst du dich gerne an Stephanie Böhm wenden, unter:
forschungsprojekt.eule@googlemail.com .

Einverständniserklärung für teilnehmende Schüler:
Hiermit bestätige ich, dass ich oben stehenden Text gelesen habe und an der Schlafmobil-Studie teilnehmen möchte. Im Rahmen des Unterrichts bin ich ausführlich von Frau Böhm über Ziele und Ablauf dieser Studie, sowie über die Grundlagen der Chronobiologie aufgeklärt worden. Ich habe Ziele und Ablauf der Studie verstanden und weiß, wie mit meinen Daten umgegangen wird.

Datum und Unterschrift des Teilnehmers/der Teilnehmerin:

_____

Einverständniserklärung für Eltern von teilnehmenden Schülern:

Hiermit erlaube ich meinem Sohn/ meiner Tochter: _____ , an der Schlafmobil-Studie teil zu nehmen und im Rahmen dieser nach Ausfüllen des Online-Fragebogens im Schlafmobil des Instituts für medizinische Psychologie der LMU an zwei aufeinander folgenden Nächten zu übernachten. Ich habe oben stehenden Text zu Kenntnis genommen und Ziele und Ablauf der Studie verstanden. Ich bin mit der Erhebung und Verwendung persönlicher Daten und Befunddaten nach Maßgabe der Patienteninformation einverstanden.

Datum und Unterschrift eines Erziehungsberechtigten:

_____

9.2 Consent Form for Students Older than 18 Years

INSTITUT FÜR MEDIZINISCHE PSYCHOLOGIE
Centre for Chronobiology

Ludwig-Maximilians-Universität München

Prof. Dr.rer.nat. Dr.med.habil. Till Roenneberg

Institut für Medizinische Psychologie, Goethestraße 31, D-80336 München

Goethestraße 31

D-80336 München
Tel. &49-(0)89-2180-75-608
Fax &49-(0)89-2180-75-615
e-mail roenneberg@lmu.de

München, Mai 2008

Lieber Schüler, liebe Schülerin,

Forscher des Instituts für medizinische Psychologie der Ludwig-Maximilians-Universität München – medizinische Fakultät – würden dich gerne im Rahmen einer Studie zum Schlafverhalten von Jugendlichen zu zwei aufeinander folgenden Übernachtungen im Schlafmobil „Eule" einladen. Es handelt sich bei diesem Projekt um die Studie, die bereits aussführlich im Rahmen des Biologie-Unterrichts im Kontext der Chronobiologie vorgestellt wurde. Das Ziel dabei ist, mehr über den Schlaf von gesunden Jugendlichen zu erfahren. Wie bereits in der Vorbereitungsstunde erwähnt wurde, existieren bislang noch keine Schlafprofile von Jugendlichen in Deutschland.
Die Übernachtungen finden jeweils unter Aufsicht am Wochenende, auf dem Schulhof deiner Schule statt, wo das Schlafmobil dann aufgestellt wird. Es werden EEGs abgeleitet, um u.a. zu beobachten, wann du einschläfst und wie sich deine Schlafphasen gestalten. 10 Tage vor- und 10 Tage nach der Übernachtungsphase soll ein Schlaftagebuch geführt werden. Vor der Schlafmessung wird eine kurze Befragung, inklusive einer online-Befragung mit körperlicher Untersuchung stattfinden.
Die Teilname ist FREIWILLIG und du kannst jederzeit ohne Begründung deine Teilnahme an der Studie abbrechen. Die im Rahmen dieser Studie von uns erhobenen Daten werden selbstverständlich vertraulich behandelt, gemäß dem folgenden Absatz zum Datenschutz:

„Bei dieser Studie werden die Vorschriften über die ärztliche Schweigepflicht und den Datenschutz eingehalten. Es werden persönliche Daten und Befunde von dir erhoben, gespeichert und verschlüsselt (pseudonymisiert), d.h. weder dein Name noch deine Initialen oder das exakte Geburtsdatum erscheinen im Verschlüsselungscode.
Im Falle des Widerrufs deiner Einwilligung werden die pseudonymisiert gespeicherten Daten vernichtet.
Der Zugang zu den Originaldaten und zum Verschlüsselungscode ist auf Prof. Roenneberg und Stephanie Böhm beschränkt. Die Unterlagen werden im Institut für medizinische Psychologie der LMU München aufbewahrt. Nach Abschluss der Studie werden die Originaldaten vernichtet. Dies wird voraussichtlich bis Dezember 2011 geschehen.
Eine Entschlüsselung erfolgt lediglich in Fällen, in denen es die Sicherheit erfordert („medizinische Gründe") oder falls es zu Änderungen in der wissenschaftlichen Fragestellung kommt („wissenschaftliche Gründe").
Im Falle von Veröffentlichungen der Studienergebnisse bleibt die Vertraulichkeit der persönlichen Daten gewährleistet."

Bei Fragen kannst du dich gerne an Stephanie Böhm wenden, unter:
forschungsprojekt.eule@googlemail.com.

Einverständniserklärung für teilnehmende Schüler:
Hiermit bestätige ich, dass ich oben stehenden Text zur Kenntnis genommen habe und an der Schlafmobil-Studie teilnehmen möchte. Im Rahmen des Unterrichts bin ich ausführlich von Frau Böhm über Ziele und Ablauf dieser Studie, sowie über die Grundlagen der Chronobiologie aufgeklärt worden. Ich habe Ziele und Ablauf der Studie verstanden. Ich bin mit der Erhebung und Verwendung persönlicher Daten und Befunddaten nach Maßgabe der Patienteninformation einverstanden.

Datum und Unterschrift des Teilnehmers/der Teilnehmerin:

_____

Einverständniserklärung für Eltern von teilnehmenden Schülern:
Hiermit erlaube ich meinem Sohn/ meiner Tochter: _____ , an der Schlafmobil-Studie teil zu nehmen und im Rahmen dieser nach Ausfüllen des Online-Fragebogens im Schlafmobil des Instituts für medizinische Psychologie der LMU an zwei aufeinander folgenden Nächten zu übernachten. Ich habe oben stehenden Text zu Kenntnis genommen und Ziele und Ablauf der Studie verstanden. Ich bin mit der Erhebung und Verwendung persönlicher Daten und Befunddaten meines Kindes nach Maßgabe der Patienteninformation einverstanden.
Datum und Unterschrift eines Erziehungsberechtigten:

_____

9.3 Consent Form for the Publication of Fotos

INSTITUT FÜR MEDIZINISCHE PSYCHOLOGIE
Centre for Chronobiology

Ludwig-Maximilians-Universität München

Prof. Dr.rer.nat. Dr.med.habil. Till Roenneberg, Stephanie Böhm
Institut für Medizinische Psychologie, Goethestraße 31, D-80336 München
Goethestraße 31
D-80336 München
Tel. &49-(0)89-2180-75-608
Fax &49-(0)89-2180-75-615
e-mail forschungsprojekt.eule@googlemail.de

Hiermit gestatte ich die Veröffentlichung von Fotos meiner Tochter/meines Sohnes_____ im Rahmen des Forschungsprojektes „Eule“ des medizinsch-psychologischen Instituts der LMU München. Die Fotos dienen einer weiteren Information der Öffentlichkeit über unsere Studie zum Schlaf von Jugendlichen.

_____
Ort, Datum und Unterschrift eines Erziehungsberechtigten

9.4 Anamnesis Sheet

Patientenname:

Geburtsdatum:

Aufnehmender Arzt: _____

Hausarzt: _____

Haupt-Diagnose:

_____

_____

Sonstige Diagnosen:

_____

_____

ANAMNESE

Familien-Anamnese:

_____

_____

_____

☐ Tuberkulose
☐ Hypertonie
☐ Schlaganfall
☐ Herzinfarkt
☐ Epilepsie
☐ Geisteskrankheiten
☐ Krebs
☐ Diabetes

Frühere Anamnese:

_____

_____

_____

Jetzige Anamnese und Beschwerden:

_____

_____

_____

_____

Soziale Anamnese: Rente: ☐ nein ☐ ja, seit: _____

Beruf jetzt: _____ früher: _____

Organsystem	Beschwerden	ja	nein
Atm./Herz/Kreisl.	Husten	☐	☐
	Auswurf	☐	☐
	Auswurffarbe: _____		
	Kurzatmigkeit, Ruhe	☐	☐
	Belastung	☐	☐
	Schlafposition: flach	☐	☐
	Erhöht	☐	☐
	geschwollene Beine/Füße	☐	☐
	Nykturie	☐	☐
	Brustschmerzen – enge	☐	☐
	unregelmäßiger Herzschlag	☐	☐
	plötzliches Herzrasen	☐	☐
	Schwindel	☐	☐
	Synkope	☐	☐
Gastrointest.S.	Appetitmangel	☐	☐
	Unverträglichkeit von Fett	☐	☐
	Kaffee	☐	☐
	Gewürz	☐	☐
	Gewichtskonstanz	☐	☐
	Schluckbeschwerden	☐	☐
	Aufstoßen	☐	☐
	Sodbrennen	☐	☐
	Völlegefühl	☐	☐
	Blähungen	☐	☐
	Zunehmender Bauchumfang	☐	☐
	Erbrechen	☐	☐
	Durchfall	☐	☐
	Verstopfung	☐	☐
	Stuhlfarbe		
	Teerstuhl	☐	☐
	Entfärbter Stuhl	☐	☐
	Fettstuhl	☐	☐
Urogenitaltrakt	Tröpfeln	☐	☐
	Inkontinenz	☐	☐
	Brennen b.Wasserlassen	☐	☐
	Startschwierigkeiten	☐	☐
	Urin: dunkel	☐	☐
	Blutig	☐	☐
	Trübe	☐	☐
	Steinabgang	☐	☐
	Nierenschmerzen	☐	☐

Neurologie	Schwindel	☐	☐
	Konzentrationsstörung	☐	☐
	Kopfschmerzen	☐	☐
	Sehstörungen	☐	☐
	Ohrensausen	☐	☐
	Heiserkeit	☐	☐
	Krämpfe	☐	☐
	Sprachstörungen	☐	☐
	Gangstörungen	☐	☐
	Lähmungen	☐	☐
	Bewusstlosigkeit	☐	☐
Extremitäten	Wadenschmerzen: in Ruhe	☐	☐
	Beim Gehen	☐	☐
	Missempfindungen	☐	☐
	Kältegefühl	☐	☐
Endokrines S.	Wärmeintoleranz	☐	☐
	Kälteintoleranz	☐	☐
	Polydipsie	☐	☐
	Polyurie	☐	☐
Allgem. Angaben	Fieber	☐	☐
	Nachtschweiß	☐	☐
	Schüttelfrost	☐	☐
	Einschlafstörungen	☐	☐
	Durchschlafstörungen	☐	☐
	Juckreiz	☐	☐
	Leistungsknick	☐	☐

Menarche: _____L.J. Menopause: _____
Menses: _____/_____ Menstruationsbeschwerden: _____
Geburten: _____ Fehlgeburten: _____

Gynäkologische Untersuchung:
Behandlung: am: _____ durch: _____

Nikotin früher: _____ jetzt: _____ Alkohol: _____

Medikamente:

_____

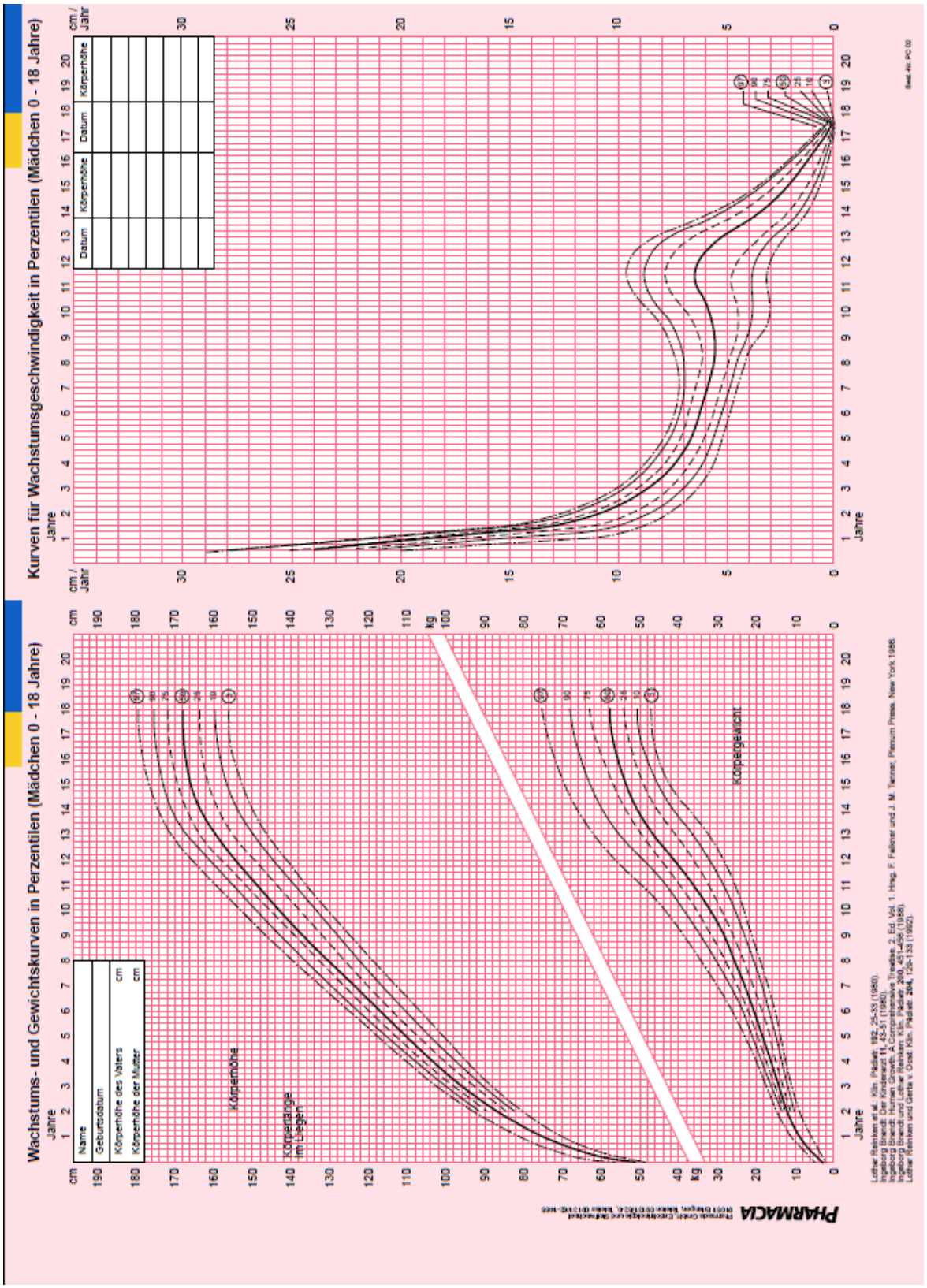
_____

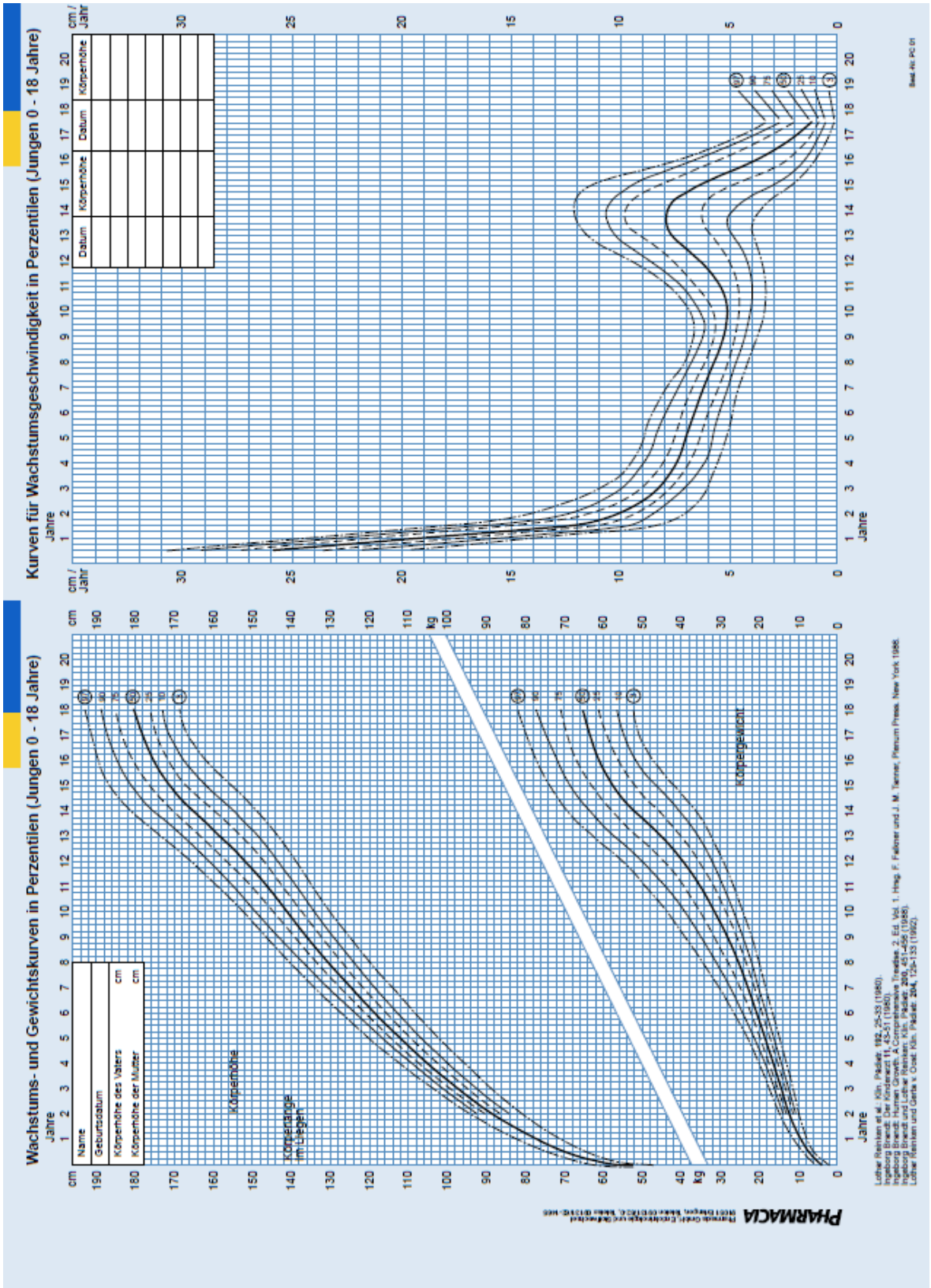
unverträgliche Medikamente / Allergien:

_____

_____

9.5 Percentile Sheets




Kurven für Wachstumsgeschwindigkeit in Perzentilen (Jungen 0 - 18 Jahre)
Jahre
cm / Jahr
Datum
Körperhöhe
Wachstums- und Gewichtskurven in Perzentilen (Jungen 0 - 18 Jahre)
Name
Geburtsdatum
Körperhöhe des Vaters
Körperhöhe der Mutter
cm
Körperhöhe
Körperlänge im Liegen
Körpergewicht
kg
PHARMACIA

9.6 WHO-5-Questionnaire

Psychiatric Research Unit
WHO Collaborating Centre in Mental Health

WHO (Fünf) - FRAGEBOGEN ZUM WOHLBEFINDEN ´
(Version 1998)

Die folgenden Aussagen betreffen Ihr Wohlbefinden in den letzten zwei Wochen. Bitte markieren Sie bei jeder Aussage die Rubrik, die Ihrer Meinung nach am besten beschreibt, wie Sie sich in den letzten zwei Wochen gefühlt haben.

In den letzten zwei Wochen …	**Die ganze Zeit**	**Meistens**	**Etwas mehr als die Hälfte der Zeit**	**Etwas weniger als die Hälfte der Zeit**	**Ab und zu**	**Zu keinem Zeitpunkt**
… war ich froh und guter Laune	5	4	3	2	1	0
… habe ich mich ruhig und entspannt gefühlt	5	4	3	2	1	0
… habe ich mich energisch und aktiv gefühlt	5	4	3	2	1	0
… habe ich mich beim Aufwachen frisch und ausgeruht gefühlt	5	4	3	2	1	0
… war mein Alltag voller Dinge, die mich interessieren	5	4	3	2	1	0

Punktberechnung
Der Rohwert kommt durch einfaches Addieren der Antworten zustande. Der Rohwert erstreckt sich von 0 bis 25, wobei 0 das geringste Wohlbefinden/niedrigste Lebensqualität und 25 grösstes Wohlbefinden, höchste Lebensqualität bezeichnen.

Den Prozentwert von 0 -100 erhält man durch Multiplikation mit 4. Der Prozentwert 0 bezeichnet das schlechteste Befinden, 100 das beste.

9.7 MCTQ

Ludwig-Maximilians-Universität München
Institut für Medizinische Psychologie
Goethestr. 31 D-80336 München

Anleitung: Dieser Fragebogen umfasst allgemeine Fragen zu Ihrer Person, sowie zu Ihrem Schlaf- und Wachverhalten. Bilden Sie gedanklich eine "Modell-Woche", die den Zeiten an Ihren normalen Arbeits- und freien Tagen entspricht. Wenn nicht anders angegeben, sollen alle Felder ausgefüllt werden.

Informationen zu Ihrer Person

Datum 2011.8.25 - 7:35

Name

eMail

(Wenn Sie keine eMail-Adresse angeben, können wir Ihnen keine persönliche Auswertung Ihres CHRONOTYPS zusenden.)

Alter

Geschlecht: ○ weiblich ○ männlich

Größe cm

Gewicht kg

Land

Wohnort

Postleitzahl

Vermittlungsinformation

Sind Sie auf diese Seite durch einen bestimmten Arzt vermittelt worden oder sind Sie Teilnehmer eines bestimmten Projektes, dann geben Sie bitte hier Ihr Kennwort an:

Regelmäßige Arbeit

Ich gehe einer regelmäßigen Arbeit nach (dies schließt Hausfrau oder Hausmann ein)?

○ Ja ○ Nein

Wenn "JA", wieviele Tage in einer Woche? ------

Anleitung: Bitte füllen Sie alle Felder aus, auch falls Sie nicht regelmäßig arbeiten. Machen Sie Ihre Angaben bitte anhand der 24-Stunden Skala (d.h. 23:00 Uhr statt 11:00 Uhr abends).

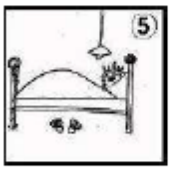
Arbeitstage

Ich gehe ins Bett um : Uhr.

Manche Menschen bleiben noch eine Weile wach, wenn sie im Bett liegen!

Ich bin bereit einzuschlafen um : Uhr.

Um einzuschlafen, brauche ich Minuten



Ich wache um : Uhr auf.,

- mit Wecker
- ohne Wecker

Ich stehe auf nach Minuten.

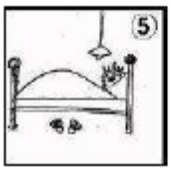
Freie Tage

Ich gehe ins Bett um : Uhr.

Manche Menschen bleiben noch eine Weile wach, wenn sie im Bett liegen!

Ich bin bereit einzuschlafen um : Uhr.

Um einzuschlafen, brauche ich Minuten.



Ich wache um : Uhr auf.

- mit Wecker
- ohne Wecker

Ich stehe auf nach ____ Minuten.

KOMMENTARFELD: Bitte geben Sie HIER an, falls Sie zurzeit KEINE Möglichkeit haben Ihre Schlafzeiten selbst zu bestimmen (z.B. wegen eines Haustieres, wegen Kind(er) etc.). Nutzen Sie dieses Feld auch um zusätzliche Informationen zu geben, falls diese vom System erfragt werden:

Aufenthalt im Freien

Im Durchschnitt halte ich mich so lange draußen bei Tageslicht auf (ohne Dach über dem Kopf):

An Arbeitstagen ____ Stunden ____ Minuten

An freien Tagen ____ Stunden ____ Minuten

Senden | Zurücksetzen

Ludwig-Maximilians-Universität München
Institut für Medizinische Psychologie
Goethestr. 31 D-80336 München

Arbeitszeiten

Ich war innerhalb der letzten 3 Monate als Schichtarbeiter tätig.

○ Ja (bitte weiter bei ?Meine Arbeitszeit ist ...?) ○ Nein

Meine übliche Arbeitszeit beginnt um:

____ : ____ Uhr

Meine übliche Arbeitszeit endet um:

____ : ____ Uhr

Meine Arbeitszeit ist ...

○ ... sehr flexibel.
○ ... ein bisschen flexibel.
○ ... eher nicht flexibel.
○ ... sehr unflexibel.

Zu meinem Arbeitsplatz gelange ich ...

○ ... in einem geschlossenen Fahrzeug (z.B. Auto, Bus, U-Bahn).
○ ... nicht in einem geschlossenen Fahrzeug (z.B. zu Fuß, mit dem Rad).
○ Ich arbeite zu Hause.

Für den Hinweg zum Arbeitsplatz benötige ich täglich

circa ____ Minuten

Für den Rückweg zum Arbeitsplatz benötige ich täglich

circa ____ Minuten

Senden | Zurücksetzen

9.8 Students' MCTQ

Ludwig-Maximilians-Universität München
Institut für Medizinische Psychologie
Goethestr. 31 D-80336 München

Instructions: The following questionnaire will ask you questions in regards to your sleep and wake behaviour. Please respond to the questions according to your perception of a standard week, based on your most current living conditions. All fields are required unless otherwise specified. This questionnaire is separated to several pages.

Personal Information

Date	2011.8.25 - 7:26
Name	
Email	(We cannot send you a personal assessment of your chronotype if you do do not provide an email address.)
Age	
Gender	○ Girl ○ Boy
Height	cm
Weight	kg
Country	
City	
Postal Code	

Referral Information

If you were referred to this site by a particular doctor or if you are part of a specific project, then please enter the keyword or key phrase that you were given below:

Days per week I visit School/Play- or Kindergarten

Do you have a regular school (or regular playgroup or kindergarten) schedule (this applies if you get up at certain times because your parents or siblings have to get up regularly)

○ Yes ○ No

If ?YES?: On how many days per week is that true? .....

Instructions: Please complete all of the following sections, regardless of whether you are working on a regular basis or not. Use the 24 hour scale, for example 23:00 instead of 11:00PM!!!!

On days I visit School/Play-or Kindergarten

I go to bed at : o'clock.

Please note! Some people stay awake for some time when in bed!

I actually get ready to fall asleep at : o'clock.

I need minutes to fall asleep.

I wake up at : o'clock.,

- I am woken by an alarm clock or my parents
- I wake up by myself

After minutes, I get up.

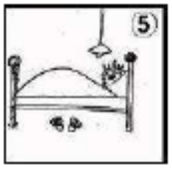
Free Days

I go to bed at : o'clock.

Please note! Some people stay awake for some time when in bed!

I actually get ready to fall asleep at : o'clock.

I need minutes to fall asleep.



I wake up at : o'clock.

- I am woken by an alarm clock or my parents
- I wake up by myself

After [ ] minutes, I get up.

Please use the blank field below to leave a comment if you currently have NO possibility of freely choosing your sleep times (e.g. because of pet(s), parents that might wake you up etc.). Use this field also to provide additional information, if the system asks for it:

[ ]

Daylight Exposure

On average, how long per day, do you spend outside exposed to daylight (without a roof above your head)?

On days I visit School/Play-or Kindergarten	[ ] hours	[ ] minutes
On Free-Days	[ ] hours	[ ] minutes

Save entries and proceed | Reset entries

Ludwig-Maximilians-Universität München
Institut für Medizinische Psychologie
Goethestr. 31 D-80336 München

School / Kindergarten Details

Do you go to school (or a regular playground or kindergarten) during the week?
○ Yes ○ No

At what time does your school (regular play/kindergarten) START?
START at [ ] : [ ] o'clock

At what time does your school (regular play/kindergarten) END?
END at [ ] : [ ] o'clock

How flexible is your school (regular play/kindergarten)schedule?
○ Very flexible
○ A little flexible
○ Rather inflexible
○ Very inflexible

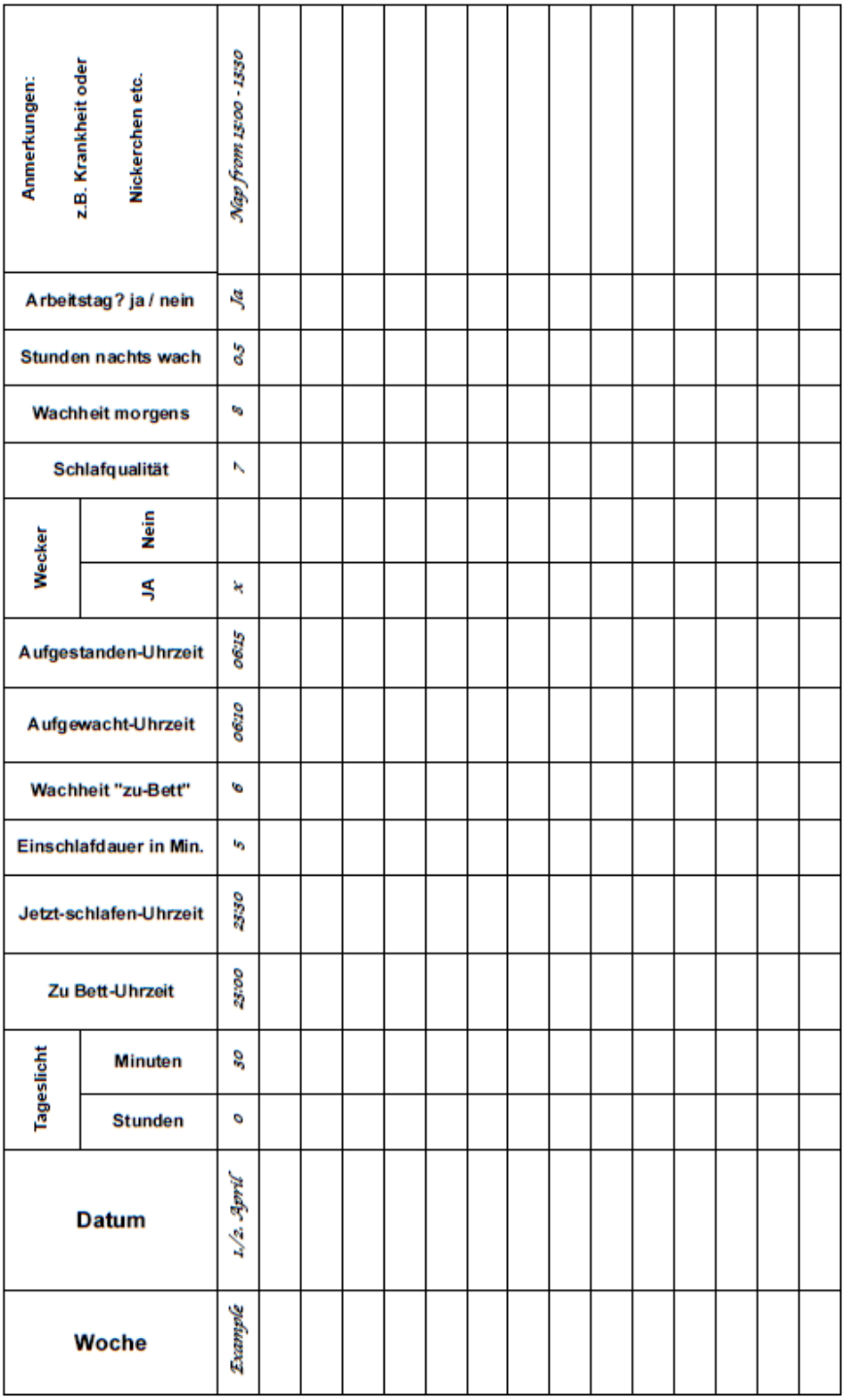
How do you travel to school (regular play/kindergarten)?
○ Within an enclosed vehicle (e.g. car, bus, underground etc.)
○ Not within an enclosed vehicle (e.g. by foot, bike etc.)
○ I stay at home.

How long does it take you to travel TO your school (regular play/kindergarten)?
approximately [ ] minutes

How long does it take you to travel FROM your school (regular play/kindergarten)?
approximately [ ] minutes

Save entries and proceed | Reset entries

9.9 Sleep Log



Anmerkungen: z.B. Krankheit oder Nickerchen etc.		*Nap from 15:00 - 15:30*															
Arbeitstag? ja / nein		*Ja*															
Stunden nachts wach		*0.5*															
Wachheit morgens		*8*															
Schlafqualität		*7*															
Wecker	Nein																
	JA	*x*															
Aufgestanden-Uhrzeit		*06:15*															
Aufgewacht-Uhrzeit		*06:10*															
Wachheit "zu-Bett"		*6*															
Einschlafdauer in Min.		*5*															
Jetzt-schlafen-Uhrzeit		*23:30*															
Zu Bett-Uhrzeit		*23:00*															
Tageslicht	Minuten	*30*															
	Stunden	*0*															
Datum		*1./2. April*															
Woche		*Example*															

Nummer .....

10 List of Abbreviations

An abbreviation followed by _w stands for "on workdays", while _f abbreviates "on free days", respectively. An ending on _cor stands for corrected values. For average values, the common symbol Ø is used. Abbreviations may also end on _MCTQ, _Zeo, or _SL (= Sleep log), depending on the source of the named item. The following abbreviations are listed in alphabetical order:

Al	Alarm
ANOVA	Analysis of variance
Aw	Awakenings
ARAS	Ascending arousal system
BT	Bed-time
BIS	Bispectral index
EN	End of night
EOG	Electrooculogram
EEG	Electroencephalogram
GABA	Gamma-amino-butyric acid
ipRGC	Intrinsically photosensitive Retinal Ganglion Cells
LE	Light exposure
LO	Lights out
MS	Mid sleep
MSF	Mid sleep on free days
MSF_{sc}	Mid sleep on free days corrected for sleep debt on work days
MSF_{sasc}	Mid sleep on free days corrected for sleep dept on work days, age and sex.
MSLT	Multiple Sleep Latency Test
MSW	Mid sleep on work days
PSG	Polysomnography
rANOVA	Repeated measures ANOVA (q.v. ANOVA)
REMP	REM-phase

SC	Sleep cycle
SD	Sleep duration
SE	Sleep end / “rise time”
ØSD	Average weekly sleep duration
SD	Sleep duration
SDSORT	Sleep-phase duration from sleep onset to rise time
SE	Sleep end
SI	Sleep inertia
SJL	Social jetlag
SL	Sleep latency
SN	Start of night
SO	Sleep onset
SOREM	Sleep onset REM
SWS	Slow wave sleep
Stdev.	Standard deviation
TID	Time in deep sleep
TIL	Time in light sleep
TIR	Time in REM
TIW	Time in wake
TS	Total sleep
TTS	Time needed to fall asleep (=Sleep latency)
WB	Wellbeing
w_f_Disc	Discrepancy between SD on schooldays and free days

11 Curriculum Vitae

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1997:	Abitur at Gymnasium Johanneum, Lingen
1997-1998:	Yoga-Certificate, Bihar School of Yoga, Munger, India
1998-1999:	Yoga Teacher at VHS Lingen
1999-2003:	Bachelor of Natural and Complementary Medicine, Southern Cross University, Lismore, NSW, Australien
2003:	Nursing Internship at Bonifatius Hospital, Lingen
2003-2004:	Medical Studies, Goethe-University, Frankfurt a.M.
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2010:	State Examination and Licensure as a Physician
2010-2011:	Dissertation/Present Thesis, Institute of Medical Psychology, LMU Munich
2010/2011:	Instructor for Seminars in Medical Psychology, LMU, Munich
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