Sleep, Teens and Blue Screens

Research into the Sleep Patterns of 16 to 17-year-old Students and How They Are Affected by Exposure to Mobile Phone Screens

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Introduction

Biology was and is my favourite subject at school, and what I hope to go on to study at university, so I knew I wanted to do my Research Project in this field. I had heard through a teacher of a mobile phone application that monitored sleep, and he suggested I use it as a base for my research. The idea captured me immediately, and I started testing it and comparing it to other apps straight away, as well as forming a bibliography to work from.

I first decided to use the students in my year as the subjects for my experiment, so therefore my question was:

"Are 16-17-year-olds' sleep affected by the amount of time they spend on a mobile phone before bedtime?"

I had to overcome some difficulties with this, as there were different apps that worked for each operating system (Android and iOS). I also had some trouble getting people to cooperate in the experiment, as I was asking more of them than most 2nd year students would for their Research Projects, as will be explained in the Practical Framework. Despite this I was still able to find a concrete hypothesis and a way of carrying out the experiment. My hypothesis was:

"If a teenager spends more than 50 minutes on their phone before going to bed, then they will sleep less deeply than one who has not spent that time exposed to blue light."

The main goals in this research are (1) to research sleep as a whole, how it works and what factors can affect it; (2) to analyse the effects of sleep deprivation, (3) to study the effects of blue light and the ever-increasing use of technology on sleep, (4) to test the hypothesis, through the experiment, to see if the more time subjects spent on their phones the less well they slept and (5) to establish if sleep apps such as *Sleepcycle* and *Sleep as Android* can be used as reliable instruments for scientific research.

Despite the obstacles, I have very much enjoyed this research overall, though it has been challenging to teach myself *how* to research, how to use and create a bibliography, how to work with Microsoft Excel and other skills I needed for the project. I trust that what I have learnt will prove to be useful for me in my future career, as research is one of the main pathways students with Biology degrees follow after completing their studies.

May this research project prove interesting to all who read it and may it serve as a foothold to further research into the topics that appear in it.

Theoretical Framework

1. The science of sleep

Through the course of history, sleep and its importance have been constantly downplayed. In Ancient Greece, it was seen as a passive state, in which mind and body were simply put on hold for no apparent reason. It was a necessary evil or – at best – an envelope for the much more interesting act of dreaming (Mastin, 2013). Nowadays, although we know much more about how it works, we still do not know *why* we spend 30% of our lives asleep. This ignorance is probably the main reason we underrate it, or even consider it a waste of time or an illness we must do our best to cure.

1.1 Sleep – exactly what is it?

The reality is sleep is an essential life process, just as necessary to our overall health as the food we eat, the water we drink and the air we breathe, only it is much easier to neglect. It is a highly complex process, as the first half of this research explains, made up of different stages and cycles, which together carry out a physical and mental restoration.

There have been many attempts to define sleep by many different people, ranging from circadian scientists to poets. Luke Mastin has collected and compared various different ones from dictionaries and scientists, and has identified the common features. In light of these, he has come up with a general definition, affirming that sleep is "a naturally-occurring, reversible, periodic and recurring state in which consciousness and muscular activity are temporarily suspended or diminished, and responsiveness to outside stimuli is reduced" (Mastin, 2013).

1.2 Sleep-wake cycles

The sleep-wake cycle was most accurately described by Alexander Borbély in the 1980's, who proposed the two-process model of sleep-wake regulation. These are (1) the circadian rhythm and (2) the sleep-wake homeostasis.

- **Circadian rhythm or process C**. The word circadian means "recurring naturally on a twenty-four-hour cycle, even in the absence of light fluctuations". The circadian rhythm is the process through which our biological or internal body clocks, found in all the cells of the body, regulate the body's alertness levels through the circadian drives for alerting and arousal. The body clocks are synchronized by the "master circadian pacemaker" (Nuffield Department of Clinical Sciences, 2016) located in the suprachiasmatic nuclei (SCN, in the hypothalamus) in the brain (see figure 3, page 9), which coordinates the activity of the entire circadian system. If it were not for our circadian clock we would be sleeping and waking every few hours, much like cats. As it is, our internal clock's alerting system increases with every hour we are awake, balancing out the drive to sleep (homeostatic drive, see the next section).

  The circadian system is entrained to the environment, principally to light, and by this it resets itself each day to the Earth's 24-hour rotation cycle. Nonetheless, morning people or "larks" tend to have a slightly shorter cycle, whereas night people or "owls" tend to have a slightly longer cycle, though it can vary slightly depending on the individual. Humans are diurnal animals, and the circadian rhythm reflects this, so there are optimal times for falling asleep, dreaming, waking and working during the course of this cycle. And though these may vary from person to person, it is true for all human beings that we are noticeably sleepier between 1 and 4 PM, and even more so between 2 and 5 AM. (Dubuc, 2012)

- **Sleep-wake homeostasis or process S**. The general term homeostasis describes any biochemical system that regulates the body's internal environment. In the case of the sleep-wake homeostasis, it is the gradual accumulation of hypnogetic or sleep-inducing substances in the brain that regulate the cycle through the homeostatic sleep drive. It is a very intuitive operation, as it regulates the desire or "pressure" to sleep according to the length of time we have been awake. While we *sleep*, this pressure quickly diminishes, as the levels of sleep-inducing substances also decline, making it more and more likely that we wake up. On the other hand, when we are *awake*, the pressure to sleep builds up throughout the course of the day.

Though this second sleep-regulating phenomenon is much less understood than the circadian rhythm, we do know that the main sleep inducing substance is adenosine. It inhibits many of the body functions related to wakefulness, particularly those involving neurotransmitters. It is a by-product generated over the course of the day in the biochemical reactions in cells, as it is the core of ATP (adenosine triphosphate), the main energy-storage molecule. Adenosine levels in the brain rise as sleep debt builds up, and then decrease rapidly during sleep. The homeostatic sleep-drive seems to be more related to deep sleep, so the pressure to sleep is to sleep deeply and can only be relieved by doing so.

To summarize these two points, the factors that determine the onset, quality and length of our sleep are the phase of our circadian cycle and our homeostatic debt (and the interactions between these). In other words, if you sleep during the wrong stage of your circadian cycle, even if you sleep for hours, you will not wake up properly rested. In the same way, if you have only been awake a few hours it would be very difficult to go back to sleep because your sleep debt would not be large enough (you would not be under enough "pressure" to sleep) (Mastin, 2013).

Sleep debt builds up with every hour we are awake, but thankfully sleep debt is not the same as sleepiness. If it was so, we would feel much more alert at 3 in the afternoon than at 7 in the evening, and this is not the case. Our alertness levels are also influenced by our circadian rhythm, which balances out and counteracts our sleep drive. It is when this alerting signal from the biological clock diminishes that sleep drive becomes an overwhelming factor, and we feel a much greater pressure to sleep. Once we do fall asleep, both the sleep drive and the alerting signal decrease rapidly, allowing us to sleep straight through the first half of the night. After this, the simple absence of the alerting signal and the lack of sleep drive mean it would be hard to maintain sleep, if it were not for the same internal clock that now sends sleep-promoting signals to the brain. In this way, the circadian rhythm and the homeostatic sleep drive interact to create long, stable periods of sleep and wakefulness.

These two processes are determined in large measure by the individual's genes, but there are also many external factors such as nutrition, physical activity, personal health and many others that also have a large influence on sleep, as is studied in point 3.

1.3 Sleep and the brain

As mentioned before, the area of the brain that regulates the sleep-wake cycle is the suprachiasmatic nucleus (SCN), located in the hypothalamus of the brain, one on each brain hemisphere (see figure 3). It is a tiny area, and contains 20,000 neurons which send signals to the rest of the body, regulating the internal body clock. Interestingly, the neurons work on a 24-hour cycle, and will do so independently if extracted from the SCN, but when they are together they work in synchrony. This is why it has received the name “master circadian pacemaker”, as it synchronizes all the cells in the body.

This internal body clock runs on a 24-hour schedule, though it can be slightly longer or slightly shorter depending on the person, as mentioned before. The reason it is so accurate is because it adjusts itself to the light-dark cycles, through Zeitgebers (literally “time-givers” in German) (Mastin, 2013), and the most important of these is daylight. Once it is adjusted, melatonin, the sleep-inducing hormone secreted by the pineal gland in the brain, and cortisol, the waking hormone secreted by the adrenal gland, are either released or inhibited, depending on the time of day. The biological clock does not actually need light to function, it uses it only to correct small timing errors, and avoid the accumulation of these (a long length of time away from light will significantly alter the circadian rhythm though).

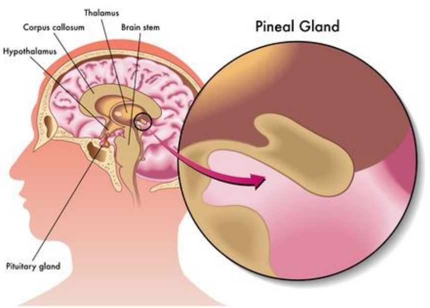


Figure 2 Pineal Gland in the Brain

Source: http://blisscodedsound.com/third-eye-pineal-gland-activation

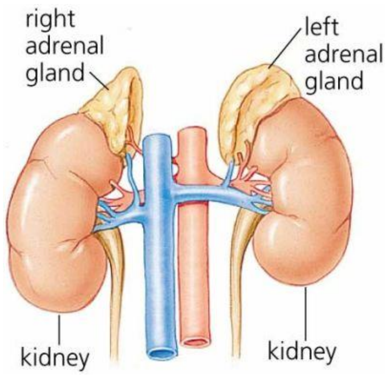


Figure 1 Adrenal Gland

Source: Pyro-Energen, http://www.pyroenergen.com/articles10/mysterious-hypertension.htm

As well as keeping the body clock synchronized to external light, the SCN also coordinates the sleep-wake cycle through the circadian drives for alerting or arousal, involving neurons, various neurotransmitters and different areas of the nervous system (Luz, 2008). This alerting pulse is the one that counteracts the homeostatic sleep pressure.

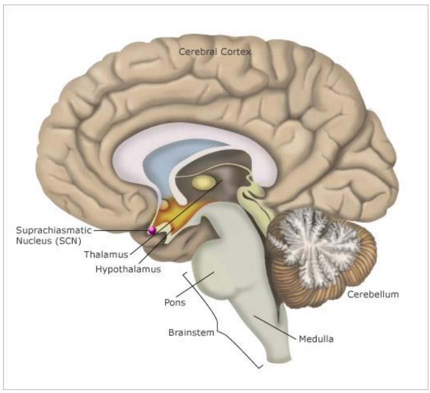


Figure 3 Suprachiasmatic nucleus in the brain,

Source: Harvard Medical School, http://healthysleep.med.harvard.edu/image/200

1.4 Stages of sleep

Sleep can be classified into two broad types: rapid eye movement (REM) sleep and non-rapid eye movement (non-REM) sleep, sometimes referred to as “active or paradoxical sleep” and “quiet sleep”, respectively. The latter one can further be divided into three separate stages (N1, N2 and N3). The cerebral physiological changes of these phases are worthy of mention as they can be monitored and recorded with polysomnography resulting in characteristic patterns of waves that are described in each of the sections. The two types of sleep (REM and non-REM) can be as different as sleeping and wakening themselves, which is why we cannot talk about sleep as being one homogenous process. The early scientist William C. Dement described non-REM sleep as an “idling brain in a moving body”, and REM sleep as an “active hallucinating brain in a paralyzed body”.

1.4.1 Non-REM sleep

Non-REM sleep can also be divided into various stages, technically three, but the boundaries that separate these are undefined and for this reason some analyses include a fourth stage.

- Stage 1. Can be referred to as drowsy sleep, N1, NREM1, somnolence etc. and it lasts usually about ten minutes. It is the transition from wakefulness to sleep, that is, from beta and gamma brain waves to slower, more synchronized alpha waves (as recorded with polysomnography). This is a gradual progress, which is why we cannot say exactly when sleep onset takes place. “Sleep starts” (or hypnic jerks) are common during this phase, in which the person surfaces very briefly and then feels the common falling sensation. The eyes move slowly and muscle activity gradually slows, and they may well be partly aware of their surroundings during this stage, so if woken they will often feel they have not slept at all.

- Stage 2. Also referred to as N2 or NREM2. It is the first stage of sleep, in which brain waves become slower, muscle activity continues to decrease, the eyes stop moving and consciousness fades completely. The theta waves in this stage are also characterized by sleep spindles (or sigma waves) and K complexes, both short interruptions that serve to suppress outside stimuli, protecting the sleep. It is also believed they play a part in the memory consolidation and learning processes. Probably because of this, the average adult will spend more time in this stage than any other.

- Stage 3. Also known as deep sleep or slow wave sleep (SWS), as well as N3 or NREM3. By this stage the person is unaware of any stimuli from the outside environment, as the brain waves slow even further to delta waves (they still contain spindles, but much fewer than in stage 2). Core temperature, breathing and heart rate (and consequently blood pressure) are all at their lowest in this stage. Dreaming is also more common than in the other non-REM stages, though not as much as in REM sleep, and it is in N3 that all the types of parasomnia take place. This deepest phase of our sleep is the hardest to wake from, and if it occurs the person will suffer severe sleep inertia (grogginess, low alertness, disorientation, etc.). Finally, information processing and memory consolidation continue to take place during this stage, and it may be because of this that it takes up a higher percentage of children's and young adults' sleep than of the elderly's.

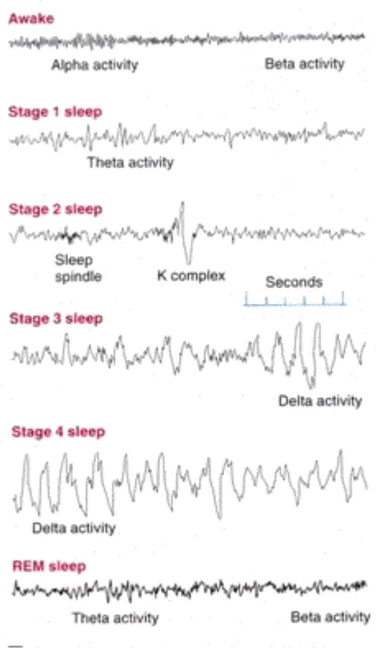


Figure 4 Electroencephalogram (EEG) of the stages of sleep

Source: http://slideplayer.com/slide/5079967/

1.4.2 REM sleep

REM sleep takes up about 20-25% of the total sleeping time, and its component in each sleep cycle increases as the night goes on, which is why it dominates the latter half of the sleep period. Also, the amount of REM sleep for a baby is much higher than that of a full-grown adult. It is most easily identified, as its name describes, by the rapid, apparently random and intermittent eye movements from side to side. Although the reason for this is still unknown, it is thought that it is related to the visual, vivid dreams that take place during this period.

- The brain during REM sleep. This stage is characterized by low amplitude and mixed frequency brain waves, very similar to those during the waking state: alpha and even beta waves, the ones used during high level concentration. Another interesting fact related to these high frequency waves is that the oxygen consumption is even higher during REM sleep than when awake and working on a complex problem, showing the high-energy consumption.

- The body during REM sleep. Regarding the rest of the body, breathing becomes faster and is irregular, as does the heart rate, causing blood pressure to rise also. Core temperature tends to be similar to that of the environment as it is not well regulated during this stage. The muscles become paralyzed and tense during this stage also, because the brain impulses for these functions are totally suppressed (except those related to the eye-movements and other functions such as breathing that keep us alive). It is believed that the reason for this muscle irresponsiveness is to keep us from acting out dreams and coming to physical harm. Sexual arousal is also common during REM sleep, regardless of whether the dreams taking place are erotic.

Although lack of REM sleep seems to have surprisingly few negative effects, it is vital for learning complex tasks, especially at the early stages of life when it takes up such a large percentage of the sleep time (around 80%). It is also true that if REM is repeatedly neglected or shortened, it leads to REM “rebound sleep” at the next possible opportunity, that is slipping straight into it instead of first going through the stages of non-REM sleep.

2. Why do we need sleep?

As mentioned before, until relatively recently it was believed sleep was a passive, inactive period in which both body and mind were put on hold, as a “necessary evil” (Mastin, 2013). In recent years it has become much clearer that sleep is more like a second state of our bodies, in which the mind is at times incredibly active, and which is entirely necessary for the great majority of animals. We know that without sleep the wellbeing of our bodies is affected and in extreme cases we will ultimately die. As scientists have acquired a greater understanding of how sleep works they have been more capable of tackling the question of why we sleep, but it remains very much a mystery. In the words of sleep researcher William Dement, “As far as I know, the only reason we need to sleep that is really solid is because we get sleepy.” (McKay, 2014)

There have been several different theories formed about the reason for sleep. Most likely it is a combination of some or all of these, as there is evidence to both support and challenge all of them.

2.1 Inactivity theory

This was one of the earliest theories to explain the need for sleep, and is based on the evolutionary idea that inactivity serves as a survival function keeping an animal out of harm when they would be particularly vulnerable. Therefore, those animals that were more adapted to their environment would remain still, in a period of quiescence while their predators were hunting and would consequently be more likely to survive. Then through natural selection this inactivity or quiescence period evolved into what we now know as sleep.

But this theory does not explain why sleep should leave us so vulnerable and defenceless, as our bodies are often paralyzed and our minds disconnected from outside stimuli. It would make much more sense to us to be conscious and alert at these critical times. The inactivity theory also does not explain why animals such as lions, that have so few predators, sleep for so many hours.

2.2 Energy conservation theory

This theory is often related to the inactivity theory, and describes sleep as a period of down time in which to save and build up energy resources, like recharging a battery. This theory is supported by the fact that one of the main factors in natural selection is the search for energy resources, such as food, and that therefore the primary function of sleep is to reduce the individual's demand on these resources at a time when it is least efficient to search for them. Research has also shown that the energy metabolism of warm-blooded animals such as mammals or birds is significantly reduced during sleep. For example, core temperature decreases 1ºC in humans when we sleep, meaning we spend less energy on maintaining body temperature. Furthermore, it has been proven that the animals that sleep the most are those with the highest metabolic rates, that is, the ones that need the most energy recharge.

On the other hand, it is actually only in non-REM sleep that the body uses less energy, as during REM sleep the brain waves are often of a higher frequency than those during waking hours, incredibly. In fact, sleep metabolism is only reduced about 5-10% in humans, which means for every 8 hours we sleep we only save the amount of energy in a slice of toast! (Mastin, 2013). Although many evolutionists would claim even a small energy saving is vital, the high unresponsiveness and vulnerability of the individual during this time seems a very high price to pay for it.

2.3 Restorative theory

Another explanation for why we sleep is based on the belief that during sleep the body repairs and rejuvenates itself. We can see this in things such as the renewing of tissue and nerve cells, muscle growth and growth hormone release, some of which happen solely during sleep. It has also been tested and proved that in animals deprived of sleep the immune system shuts down and they die in a matter of weeks. Sleep-deprived humans have also shown less than half the protective antibodies of those with healthy sleep patterns. More recently, it has been established that during sleep all the biochemical waste is actively washed out of the brain through the so-called glymphatic system. Thus, sleep deprivation may induce accumulation of toxic substances.

We can divide the restoration process between the different stages of sleep, as it seems physical restoration occurs mainly during non-REM sleep, whereas brain repair happens during REM sleep. It does seem to make logical sense that during slow-wave deep sleep the body should focus on healing and repairing damage, and that the more mentally active period should be dedicated to brain restoration. Because of this, athletes and growing children spend considerable more time in deep slow-wave sleep, as does anyone after having done intense physical activity.

Another supportive fact for the restoration theory is that the body's metabolic activity during sleep is mainly anabolic, as opposed to catabolic, that is, building molecules up instead of breaking them down. This also seems to be universal across the animal kingdom, right down to the smallest unicellular organisms.

On the other hand, there is one argument to counteract this theory, and that is that scientists have not yet found what the function of stage 2 non-REM sleep is, which takes up 50% of the average adult's sleep period. Furthermore, though we can see much repair work done during sleep, it is still not clear if it happens more *then* than during waking hours. Nonetheless, the restorative theory is a widely-supported theory and is likely one of the main causes for sleep.

2.4 Brain plasticity theory

One of the more recent theories for sleep is based on the finding that it is related to structural and organization changes in the brain (brain plasticity). It has become very clear, for example, that sleep is related to early brain development in infants and babies. They spend so much time sleeping because they are acquiring information and skills much faster than at any other point in life. This is also why young children spend so much more time in REM sleep than adults, as it is in this stage that the most brain activity and renewal happens. In addition, studies in animals have shown that sleep significantly enhances brain connections, and that those allowed to sleep after an environmental change adapt much quicker to the new stimuli (Mastin, 2013). It seems that the muscle atonia that we suffer during REM sleep also allows synaptic connections to be established without any dangerous motor consequences.

The brain plasticity theory seems, like the restorative theory, to be one of the most likely reasons for sleep, though it is also true that other aquatic mammals such as whales and dolphins spend little or no time in REM sleep as infants, which increases as they grow older.

3. External factors that affect sleep

Although the circadian rhythm and sleep homeostasis are the two processes that regulate the sleep-wake cycles of the body, there is a huge range of external factors that can affect the quality and length of sleep too. Only some of the major ones are explained here; there are others, and scientists are constantly discovering other seemingly unlikely factors.

3.1 Nutrition

We see the links between diet and sleep in everyday situations: the sleepiness experienced after eating a heavy meal, or the craving for caffeine to wake up or stay awake. It turns out the food we ingest is not only crucial for fuelling our bodies during the day but also for winding down at night.

3.1.1 The bad diet – bad sleep cycle

Amongst the range of health disorders that sleep deprivation has been proven to cause we find obesity, and this is obviously linked to nutrition. The more tired a person is, the more he or she will probably eat during the day to stay awake, though they often do not realize that this may be the reason they are increasing their ingestion. If this habit is prolonged, it eventually leads to weight gain and obesity. On the other hand, eating a lot of the "wrong things" (such as processed or fast food) during the day, or any type of heavy meal late at night, has also been shown to impact sleep negatively. So there is a never-ending cycle of unhealthy eating and unhealthy sleeping.

There is not a set menu that brings better sleep, but there are certain small modifications that can be made for a more restful night. Following these should avoid the unending cycle of sleeping poorly, drowning in caffeine the next morning, craving sugar all day and sleeping badly again.

The first piece of advice we receive from every dietitian is to eat balanced, nutritious and varied food throughout the day, evenly spaced out. If we do not eat enough during the day, we will overeat late in the evening and then suffer indigestion when trying to fall asleep. Also, if we do not eat *enough* in the evening we will be tossing and turning on an empty stomach. It is a useful habit to go to bed and get up around the same time every day, according to experts, as this keeps the brain and stomach's sleep schedules synchronized.

3.1.2 So, what food?

→ **Avoid sugar and caffeine**. As disappointed as people may feel reading those words, there is no doubt as to the negative effects of these on sleep. But, as with everything, consuming them in moderation is fine. According to the National Sleep Foundation, more than three cups of coffee a day will impact sleep, and six or more is excessive (National Sleep Foundation, 2016). It is good to keep in mind that the body takes around 6 hours to metabolize caffeine fully, though each person's body is different. As for sugar, it is commonly known that it gives us energy boosts, so logically it is not a good idea to encourage those near bedtime. (Hauser, 2016)

→ **Avoid alcohol and nicotine**. Alcohol is a deceptive substance, as it allows the person to fall asleep almost instantly, and often will take them into a very deep sleep, but he or she will not experience the proper cycles. Instead they will have a very disrupted sleep with frequent awakenings, and they will not feel refreshed when they wake up. As for nicotine, consuming tobacco too close to bedtime can disrupt sleep, but the desire for it can even waken the person in the middle of the night. This can lead to insomnia (Peters, 2016).

→ **Complex carbohydrates**. Research shows that the best way to fall asleep quickly is to eat most of the daily recommended carbohydrates in the evening, but not too close to bedtime. This was shown in a 2007 study by giving the subjects different types of rice (higher or lower in glucose). There are theories that speculate that the insulin released by the high glucose content led to a faster secretion of tryptophan (an amino-acid found in niacin, which plays a key role in creating serotonin, a neurotransmitter associated with melatonin[1]) (Afaghi, 2007).

[1] As will be explained below in more detail, melatonin is a hormone that plays a key role in the regulation of the circadian rhythm.

→ **B vitamins.** B3 is the other name of niacin, it contributes to extending the REM cycle and limiting the number of awakenings during the night. Also, B6, found in poultry, fish, chickpeas and bananas helps create serotonin faster. Milk also contains B vitamins and tryptophan, so 3-4 servings of low-fat dairy a day are a good idea (Hauser, 2016).

3.2 Physical activity

Physical activity improves sleep quality and increases duration, firstly for the obvious reason that it tires you out. It can also help reset the biological clock, as it raises body temperature slightly, meaning there is more of a contrast when it drops later at sleep onset. It especially synchronizes the sleep-wake cycle if the exercise is done outside where we can receive sunlight, which stimulates wakefulness. Finally, physical activity reduces stress, which also allows more restful sleep, and it reduces the risk of suffering sleep disorders such as sleep apnea and restless leg syndrome (National Sleep Foundation, n.d.).

We must keep in mind, though, that physical exercise will not immediately lead to better sleep. As is being explained in this project, there are many other factors that can be affecting us that we are unaware of, but aside from that, exercise often needs to be regular for it to be effective in giving us more restful nights. This explains why sometimes a person can come home from a long day of intense physical work, fall into bed exhausted and still take a while to fall asleep (Sánchez-Mariscal, 2016).

The benefits that exercise has in relation to sleep can be seen in a study carried out by Withings, a company that produces small fitness trackers that also monitor sleep cycles (Chieh, 2014). Firstly, people who have done physical activity tend to go to bed earlier. Secondly, they experience longer sleep duration, as well as spending more time in deep sleep, the phase where muscle cells can be repaired. Finally, they do not suffer as many mid-night awakenings.

3.3 Career

3.3.1 Shift work

Nowadays the world economy relies very heavily on shift workers, especially in a 24-hour globalized society. From an economical point of view, it permits higher productivity, but the effects on the individuals who work these shifts are very damaging. They are more prone to suffer different health disorders, including heart problems, sleep disorders or even cancer. Sleepiness in any type of job can have terrible consequences, as the workers are much more likely to have accidents in the workplace or while commuting to and from work. Naturally shift workers are even more liable to these accidents. There are several million of them in the United States alone, 3.2% working night shifts and a further 2.4% working rotational shifts (different timetables every day, during the day, the night or a bit of both) (Bierma, 2016). Most of us would think of security guards or factory workers when thinking of shift work, but doctors and nurses, pilots, bridge-builders, police officers, customer service representatives and commercial drivers are all in this group as well.

The symptoms of the so-called Shift Work Disorder include excessive sleepiness at times when the person must be awake and alert; insomnia; unrefreshing sleep; difficulty concentrating, irritability, lack of energy and even difficulty in personal relationships (National Sleep Foundation, 2016). There are some helpful guidelines that can help reduce the impacts of shift work, as proposed by the National Sleep Foundation (National Sleep Foundation, 2016). To stay awake at work the following are recommended:

- Going for a walk before work. It is especially useful if this can be in daylight, as this promotes alertness.
- Drinking caffeine. Coffee and soda drinks can give energy boosts, but it is better to do this in the first half of the night as they remain in the digestive system a long time, and could put off sleep onset later.
- Taking breaks to get up and move. This too will help to stay awake.

To sleep better at home:

- Getting enough time to sleep, which means 7 to 9 hours in adults.
- Avoiding caffeine, large meals and alcohol in the hours before bed.
- Avoiding time on screens before going to bed.

3.3.2 Jet lag

This too is a part of everyday life for modern society. Jet lag refers to the symptoms experienced when switching time zone, after an aeroplane flight. These symptoms are caused mainly because the biological clock is not synchronized with the new time zone, and cannot adapt immediately. For many years, it was believed that it was simply a mindset of those travelling, but there is a biological explanation for why our body wants to sleep during the day and stay awake at night when we have changed time zone (National Sleep Foundation, 2016).

People travel so far across time zones for different reasons, we find both those who do it regularly for work reasons, and those for whom it is a one-off holiday. The solutions for jet lag do not tend to seem very effective as it simply takes time for the body to adjust to the new time zone, but there are some tips that can be followed to speed up the process. During the journey, it is a good idea to set all watches and clocks to the new time zone, to start thinking in that mindset. It is also good to drink plenty of water, as dehydration will only contribute to moodiness, and will encourage overeating. Once at the destination, going to sleep at the normal bedtime and getting as much sunlight as possible during the day can also help, as this will adjust melatonin levels (National Health Service, 2014).

3.3.3 School starting times

Recently there has been a series of studies conducted on the sleep of adolescents in relation to the time they start school. It has been proved in the past that teenagers have a biological inclination to go to sleep and get up later than people of other ages. This means that melatonin starts to be released in their brain later in the day than the average adult or younger child, and will continue being secreted until later in the morning. Therefore, the great majority of secondary school students arrive to class in a sleep deprived state (Nolan, 2011), and the consequences of this sleep deprivation are clear.

Students starting at later times proved to perform better academically, have fewer car accidents, report less depression and more motivation and be less likely to be late. In view of these, researchers proposed later starting times for high schools and universities, with the times getting later as the individuals grow older, as this biological “phase shift” intensifies over time (Barnett, 2015). Despite these findings, if the timetable changes are ever implemented in the education system it will take time, as there are obstacles such as unawareness, adult convenience and after-school activity timetables to be taken into consideration.

3.4 Sleep environment

The bedroom environment is another external factor that can affect sleep. Because the body temperature drops during sleep it is important to have a relatively cool sleep environment, so that it is easier to fall asleep. Having said that, researchers have not been able to determine a temperature range, because each person's ideal sleeping temperature is different (Harvard Medical School, 2007). Dimming lights may seem obvious, but doing so some time before going to sleep can have a significant impact, as it prepares the body for sleep (National Sleep Foundation, 2016) (explained in point 4). Wearing night masks or using block-out curtains are also possibilities, but are not crucial. It is very important not to have noise during sleep time, as this disrupts sleep very easily, and will especially prevent the individual from reaching deep sleep. Some people like background sounds while falling asleep, but these must be very low. Finally, having good mattresses and pillows, and being comfortable in general will also contribute to a more restful night.

Just as a final comment, there are some researchers that claim there are better or worse positions for sleep. Generally, our bodies tend to move to the positions in which it is easiest to breathe, that is, the one where the airway is the widest (Soong, 2011). Lying on one's back is not good for this, and can also encourage snoring, as is commonly known. Instead, sleeping on the left side can reduce heartburn for those who suffer from it (Barone, 2016), and is also meant to be good during pregnancy as it improves circulation.

3.5 Climate

Climate can also affect our sleep, as well as affecting overall health. The most obvious way is the temperature, which has already been mentioned, as lower temperature is easier to sleep in because body core temperature drops anyway. This effect can be magnified by taking warm baths or shedding extra layers just before going to a cool bed. Very warm and humid climates, on the other hand, are harder to sleep in, partly because it is just physically uncomfortable, but it also prevents the body from slipping into deep sleep.

In relation to the seasons, shorter days can also affect sleep, in that we receive less sunlight and are therefore more prone to drowsiness. There is a higher secretion of melatonin during the day, but also of serotonin, which explains increased feelings of depression and tendency to overeat. Certain seasons also bring allergies, and the anti-histamines we often take to reduce the symptoms of these can also keep us awake at night. And, of course, light illnesses such as flus and colds tend to intensify in the winter, and can also make sleeping uncomfortable.

3.6 Medical conditions

There are many different chronic diseases and medical conditions that can affect sleep. The most common ones are depression, menopause, musculoskeletal disorders (arthritis, fibromyalgia), cardiovascular disease, asthma, heartburn or GERD, eating disorders, kidney disease and thyroid disease, amongst many others (Sheehan, 2012). Sleep disruption is often just one of the symptoms of these conditions. It is also true that certain types of medication taken to treat sickness can disrupt sleep, but there are pharmaceutical solutions to improve it (normally drug treatments). These are also used to combat sleep disorders such as sleep apnea, restless leg syndrome and narcolepsy, and can either help the person to fall asleep quicker (such as Ramelteon, Rozerem) or to stay asleep for longer (Doxepin, Silenor), or both. It also must be said the great majority of these can lead to dependence on them (Mayo Clinic, 2014).

3.7 Exposure to screens

Finally, the external factor that influences sleep that most interests this research is exposure to screens. This factor is obviously one that has only appeared since the invention of these screens, but it is ever-increasing as modern society uses them for more and more things. Their influence on sleep will be analysed in depth in the next section.

4. Screens and their effect on sleep

4.1 Screens in modern society

It is widely known that the use of screens in many shapes and sizes has revolutionized modern society. It affects every area of our lives, as many have written about, in both positive and negative ways. Immediately we think of its impacts in the education system, the work place, our homes and our free time, as so many of our daily activities now involve looking at a screen for many hours. But not many of us often think of the impact it has on our health, and particularly our sleep. For most care-free teenagers, to be specific, if we have any concern at all about how screens can damage our health it is not exactly something that would keep us awake at night – or is it? So many of us are convinced we do not need as much sleep as is recommended for this stage of life, and are therefore very willing to sacrifice it in exchange for study hours or social life. We are conscious of these sacrifices and can attribute later tiredness to them, but could it be that there is another major factor affecting how much we rest that we are oblivious to?

We use our phones for all sorts of things, as cutting edge technology continues to improve devices and widen their resources. Amongst young people, the activities that stand out the most are texting and having long virtual conversations; consulting many different social media websites, playing a wide variety of games and watching videos on YouTube. Though we do these things throughout the day, for both students and working people the natural time to relax and spend some time on phones is in the evening, when we have finished working and studying. But whether we want to hear it or not, research has shown that this extensive use of mobile phones can cause significant sleep problems, especially when used in the last hour before going to bed.

4.2 The problem

Dr Thomas B Trafecanty explains the phenomenon very clearly:

> "The bright lights produced on high-quality modern phones interfere with the natural rhythm of the body, tricking our brains into believing that it is still daytime. The light stimulates the cells within the retina – the area of the eye that transmits information to the brain – informing us of what time it is. This process controls the release of the waking hormone, cortisol, and the sleeping hormone, melatonin. According to the recent study conducted by the Lighting Research Centre, a two-hour exposure to light from mobile devices can suppress melatonin production by as much as 22%." (Trafecanty, 2009)

The phenomenon will now be analysed in detail.

4.2.1 Light and its effect on us

Light is the electromagnetic radiation that can be detected by the human eye, and that is therefore responsible for the sense of sight. It occupies only a small section of the wide electromagnetic spectrum, which includes radio waves, infrared waves, visible light, ultraviolet (UV) rays, x-rays and gamma waves. All waves vary in length (measured in nanometres, a billionth of a meter) and frequency (measured in hertz). The light the human eye is sensitive to includes a range of colours, these being determined by the wave length. They range from 700 nm, red light, to 400 nm, violet light (Stark, 2016). Together all these colours form what we call white light, or sunlight. Light is also the most common form of energy, the shorter wavelengths being the ones that emit the most energy, while longer waves emit less (Tutor Vista, 2016).

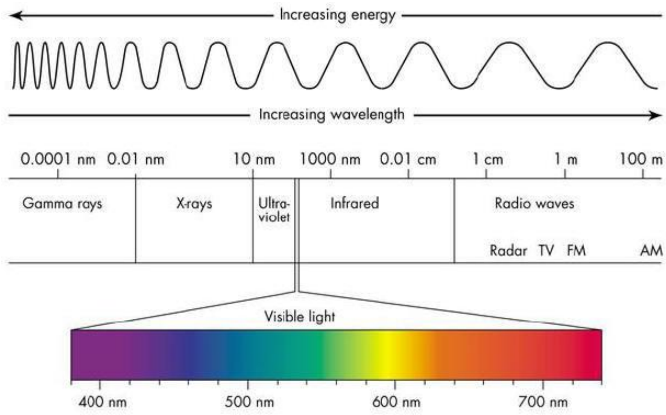


Figure 5 Electromagnetic spectrum

Source: https://9-4fordham.wikispaces.com/Electro+Magnetic+Spectrum+and+light

Right up until the late 19th century humans and all other animals lived and were limited by the rise and set of the sun: any activity outside daylight had to be done on limited resources, such as candlelight. But since Thomas Edison invented the lightbulb (1879), light has no longer been restricted to the daytime, and sunset has no longer meant the end of social life: on the contrary, for many it means the beginning of it. Everyday life since then has been just as possible at 1am as at 1pm: darkness is no longer an obstacle. Suddenly, lights in all shapes and sizes appeared, and in consequence sleep was very much underrated. In addition, only twenty years after the invention of the lightbulb the first shift workers were hired, and there was no longer any need to leave work when the sun went down.

Nowadays, we can classify the brightness of light according to the lux scale (1 lux being the brightness of a candle from 10 feet away). Any more than 180 lux is enough to disrupt our biological clock, yet we find that the average lightbulb (100 watt) is about 190 lux, and most office lighting is of 300 lux. The damages to our sleep go beyond what we can imagine.

Part of the problem were the strange ideas that Edison himself had about sleep, as David K. Randall explains:

> *Edison saw no problem as he watched the natural rhythms of sleep irrevocably change. For a reason that was never quite clear, he thought that sleep was bad for you.* “The person who sleeps eight or 10 hours a night is never fully asleep and never fully awake,” *he wrote.* “He has

> only different degrees of doze through the 24 hours." *Extra sleep made a person* "unhealthy and inefficient." *Edison saw his lightbulb as a form of nurture and believed that all one had to do was* "put an undeveloped human being into an environment where there is artificial light and he will improve." (Randall, 2012)

Furthermore, we are not the only ones that have been affected by the sudden introduction of so many bright lights. More than 100 million birds die after crashing into brightly lit buildings in North America in one night alone. And many biologists now classify artificial light as yet another threat to living organisms as unlikely as sea turtles and trees.

But to come back to our object of study, we will now look at exactly how light inhibits our ability to rest.

4.2.2 Blue light

We have all heard that UV (ultraviolet, invisible) light is harmful to our eyes as it can cause cataracts, but it turns out visible light can cause us harm, too. Blue-violet light can contribute to Age-related Macular Degeneration (AMD), the deterioration of the light sensitive tissue in the back of the eye (macula), and blue-turquoise light disturbs our sleep-wake cycle and affects memory.

Blue light is found in the 380-500nm range of wave lengths: one of the shortest and highest energy wavelengths (it is actually very similar to the UV wavelength!). So where do we find blue light? Everywhere. Any form of white light contains the whole spectrum of visible light, including the blue range, so the main source of it is the Sun, whose light surrounds us all the time. As the short wavelength waves collide with air molecules blue light is released, and actually this is what makes the sky look blue. This type of light is the one that lets our body know when it is daytime: there are about 30000 cells inside our eyes (called intrinsically sensitive photoreceptive retinal ganglion cells – a mouthful!) that react to this particular wavelength. They contain a unique light-sensitive pigment, melanopsin, that sends signals to the suprachiasmatic nucleus in the brain telling it to shut off melatonin production, the sleep-inducing hormone, and secrete cortisol, the waking hormone. It is for this reason that exposure to blue light boosts alertness, elevates reaction times and even increases sense of well-being and mood. In more scientific terms and in relation to the brain, it tends to suppress delta waves, those characteristic of deep (REM) sleep, and boosts alpha waves, the ones that create alertness.

Consequently, blue light is essential to get us going at the beginning of the day. Our circadian rhythm is always slightly out of sync when we get up in the morning, as our biological clock often runs a slightly longer or slightly shorter cycle than 24 hours, so to reset it every day sunlight is essential. It is for this reason that experts like Dr Michael J. Breus, a sleep therapist, recommend getting 15 min sunlight in the morning before starting the day. (Hill, 2015)

Aside from keeping our circadian rhythm on time and keeping us awake and alert, blue light can be beneficial in other areas, including medical treatment. Blue light therapy has been shown to be effective in the treatment of Seasonal Affective Disorder (SAD), a type of depression linked particularly to the autumn and winter. People affected by this condition are exposed to bright white light which contains a high level of HEV blue light waves. (Heiting, 2016)

4.2.3 So what is the problem with blue light?

All these ideas of high alertness levels and energy boosts sound great, so what is the problem with blue light? Well, the only reason our bodies can find new energy is because they have had a period of rest, which we obtain through sleep. We may not understand why, but it seems essential to both body and brain that we sleep, as was explained earlier on. When we do not sleep enough, what we maybe expect from our bodies is that if we keep pushing them to keep up the energy levels indefinitely they will eventually crash. This is true at a more extreme level, and we do not normally take it that far, but the reality is that in the phase *before* that, our bodies try to adapt to the inputs we give them and stop the sleepiness setting in. Therefore, if we expose ourselves to artificial blue light beyond the hours of daylight when we receive it naturally, our body will think it is still daytime, and that it still needs to be awake and alert, instead of allowing the natural onset of sleep.

To summarize, exposure to natural blue light during the day will not damage our health, because our bodies are meant to be awake and alert, so they should not be producing melatonin anyway. It is in the evening and at night that artificial blue light it is harmful, because even when it gets dark outside we are still making our bodies believe it is daytime, and therefore postponing the onset of our much-needed sleep.

And what is the main way we expose ourselves to artificial blue light? Screens. It is true that there are certain types of lightbulbs and other devices that can emit it too, but there is no questioning the fact that our main source of this type of light is our laptops, iPads, tablets, eBooks, and mobile phones. As Trafecanty explained (op. cit.), it supresses the hormone that induces sleep, meaning that even once we have turned the device off, our rest will be affected in quality and length. According to a recent study conducted by the Lighting Research Centre (Trafecanty, 2009), two hours reading emails or sending texts can mean a 22% less of melatonin production.

There are other ways in which blue light affects our health, in fact, there is a whole range of health disorders that have been linked to exposure to blue light. Although scientists do not yet know exactly how exposure to light increases the risk of suffering these disorders, it is most likely linked to the lack of sleep and disruption of the circadian rhythm. Our body clock is believed to control up to as much as 15% of our genes, and it is when these do not function correctly due to by-products of artificial light that we are more prone to disease. Health disorders that have been linked to blue light exposure include various types of cancer (breast, prostate), diabetes, heart disease, obesity and increased risk of depression (Randall, 2012).

This image from the Blue Light Exposed website summarizes well the beneficial and harmful effects of blue light:

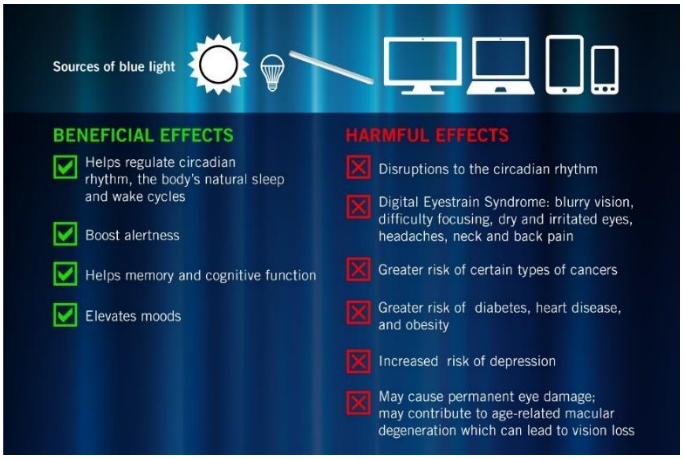


Figure 6 Beneficial and Harmful Effects of Blue Light

Source: Blue Light Exposed, http://www.bluelightexposed.com/#bluelightexposed

4.3 What can we do about it?

As the new awareness of the effects of blue light on sleep spreads, various solutions have been proposed, though none of them completely solve the problem. The only way to avoid losing sleep because of screens is to switch them all off, not look at them at all at night, and even keep them in a different room while sleeping. These are rather radical and hard-to-achieve solutions for today's technology-oriented society, and we will find most people would sacrifice an hour's sleep in exchange for the social life or entertainment they get through their phones.

Fortunately for us, however, other solutions are available in different formats. Apple and Android have each created their own settings or apps to help reduce blue light exposure. Apple has the Night Shift setting, which changes the colour of the light of your screen from cooler (bluer) to warmer (reddish yellow tint). It can be used any time, but can also be set to a schedule (to come on at sun set and off at sunrise, for example). In the case of Android, they created an app called *Twilight*, which essentially does the same thing, only it reduces blue light and increases red light gradually over the course of the day, in accordance with the sunset and sunrise times in each time zone. In fact, there is a recommended laptop app similar to *Twilight* called F.lux, which was developed by the same person who designed Sleep as Android, the app that will be used in the experiment to track the subjects' sleep.

But phone settings are not the only thing you can do to protect yourself from blue light. There are other solutions, the most popular one being orange tinted glasses. These filter out blue light, meaning that melatonin production continues basically as usual, and we eventually naturally begin to feel tired, despite having worked in front of a computer or used our phones for many hours. It is recommended that the person puts the glasses on a few hours before going to bed, and keeps them on the whole evening. It is an interesting fact that there is a big difference in melatonin production when exposed to bright light and dim light. When we use orange tinted glasses we produce almost as much melatonin as without them in dim light, whereas in bright light (which is what electronic devices produce) we hardly produce any:

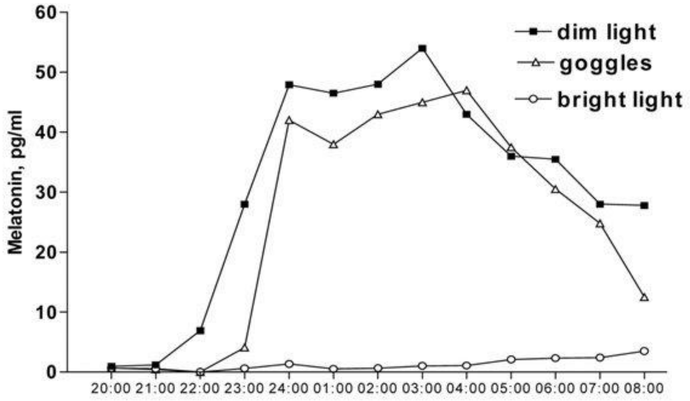


Figure 7 Graph showing melatonin production in dim light, bright light or with goggles

Source: Authority Nutrition, https://authoritynutrition.com/block-blue-light-to-sleep-better/

More recently, other protective eyewear has been designed especially for those working for many hours in front of a computer. They look just like normal glasses, but they have a special coating that reflects blue light but allows all the other light through. This avoids the eyestrain we unconsciously submit ourselves to when staring at a screen for many hours. There is also an outdoors version of this product. There are many tips that can be followed when trying to reduce eyestrain and blue light effects on our eyes and brains, and many of them can apply when using a phone too.

Figure 8 Blue light Reflective Glasses

Source: http://www.bluelightexposed.com/

Finally, there are a few other small habits that if acquired will help block blue light. Turning off all major lights in the house 1 or 2 hours before bedtime is a good idea, as well as using orange lamps instead of blue ones. Candlelight also works well as a more environmentally friendly option, and it can create a more relaxed atmosphere. Finally, sleeping in a completely dark bedroom, and/or using a facemask are things that sleep experts recommend independently of blue light exposure, and which are always good to keep in mind.

4.4 Other negative effects of using phones at night

Exposure to blue light is the key issue that using phones just before bed can cause, but there are others. Although it is not a part of this research, it is interesting to point out other ways that our phones can affect our sleep. For example, doing the activities we do on our phones stimulates our minds to stay alert when it is time for them to slow down. It may seem harmless to knock out a few emails at the end of the day, or to watch a movie or series to relax, but the reality is that doing these things can have quite the opposite effect. Surfing the web, watching videos, reading something negative or even exciting on the internet or in a text all make it hard for our brains to unwind and settle down to sleep. As with blue light, we are tricking our brain into thinking it needs to remain awake and alert, and consequently we lose length or quality of sleep, even once we have turned the device off.

There is also a more obvious way in which our phones can disturb our sleep, and that is by incoming notifications. Many people turn their phones off, onto flight mode or put them on silent before going to sleep, but there are those who do not. You may think the chimes of incoming messages do not wake you, or that even if they do you just go straight back to sleep, but they could be affecting how much you rest more than you think.

5. Results of sleep deficiency

The list of repercussions of sleep deficiency seems unending, be it because of less quantity of sleep or poor quality. Some of its effects are still being discovered, but the ones we know of range from higher likelihood of having car accidents to higher susceptibility to health conditions as serious as cancer, and everything in between. Though we may not understand exactly how or why, sleep is an absolute, indispensable need of human beings, and not prioritizing it can lead to all sorts of problems, not only health ones.

To take one of the examples already mentioned, the number of car accidents that have been attributed to drowsiness in the USA in a year is 100,000; and this figure is most likely only the tip of the iceberg, as it is hard to attribute crashes to sleepiness (National Sleep Foundation, 2016). These have brought about some 1,550 deaths. In this same poll (*Sleep in America*), 60% of adult drivers admitted to driving a car while feeling sleepy, of which 37% said they had even fallen asleep at the wheel! Furthermore, some 11 million drivers said they had been in accidents or near-accidents because of drowsiness.

Some of the health consequences caused by lack of sleep have already been explained, but it is not only our health that can suffer when we do not get the rest we need. There have been studies that have shown correlations between sleep deficit and poorer quality of life in general, particularly in personal relationships (Harvard Medical School, 2011). This happens most often in sleep disorders such as insomnia and sleep apnea, which often lead to depression. Sleep deprivation hurts a person's sense of humour, their irritability and patience levels, their decision making and general sense of happiness, which are all things that can negatively affect their personal relationships (DiDonato, 2014). There are other studies that show that teens who sleep well are the ones most likely to have healthy, supportive relationships (Entin, 2013).

Finally, it is important to mention one other large area of an adolescent's life that is affected by their sleep habits. The academic performance of students, once again, is determined by a huge range of factors that cannot possibly be controlled, but too often society attributes a person's academic achievement to their intellectual capability. Recent scientific research shows that the quality and quantity of a student's sleep can deeply affect their performance and grades (al., 2015), and young people studying in both high schools and universities are very much unaware of this. The common habit of studying into the early hours of the morning or even all night before an exam actually works against students' chance of doing well, according to sleep specialists (Harris Health System, 2012). They recommend getting 8-9 hours of sleep, especially on nights before exams, as sleep is the time when the learning process takes place, and the body consolidates memory. Without it, it is much harder to retain the concepts the person has studied or memorized. They also suggest studying during the periods of optimal brain function, between 6 and 8pm, and avoiding early afternoons, which are usually the times of least alertness. Finally, as mentioned before, they advise minimum use of caffeinated drinks, as the caffeine will remain in the system for as long as 8 hours, meaning that often even once the person has decided to stop studying and sleep, they cannot do so.

Though the results of sleep deficiency were not the central object of study for this research project, they may serve as a warning for anyone who reads it, and as a prompt to make small, non-drastic changes to one's sleep life. Considering all the aspects studied it may well be that it is one of the causes or contributors to any number of health problems, and most of us are not even aware of it. It does not take a huge effort to cut down on sleep-depriving foods, get that extra little bit of exercise or find a non-screen activity to do before bedtime, and our bodies may appreciate it in more ways than we might think.

Practical framework

6. Explanation

For the practical side of this research project an experiment was carried out on the sleep of the people in my year at school, that is, 16 – 17 year olds. It is widely known how much mobile phones and screens in general can affect the lives of young people. This includes their sleep, though it is an area that we are not always so aware of.

To carry out the experiment, the resource used were applications that could be easily downloaded onto the phones of the students, to monitor their sleep. In the case of the iOS operating system it is the *Sleepcycle* app, and for Android users it is *Sleep as Android.* These apps are free and are the most recommended for monitoring sleep, though most people use them as more effective alarm clocks. An explanation of how each of them works will now be provided.

6.1 iOS Sleep App

In the case of the iOS app, *Sleepcycle*, it uses sound analysis to identify sleep states by tracking movements in bed. Our movements vary depending on the sleep phase, as explained in point 1.3, because during non-REM sleep our muscles are paralysed to restrain us from acting out our dreams, whereas it is not so in REM sleep. *Sleepcycle* has two motion detection modes. The recommended one (and the one most commonly used) is the built-in microphone of the phone, which detects the sound we make as we move in bed. This is the one that has been used in this experiment, because it is the most accurate and because there is no need to put the phone in the bed – having it on a night stand nearby is sufficient. There is another option, and that is using the phone's accelerometer (the part than can detect when you turn the phone sideways), but this seems to be less efficient than the microphone, and how well it works can depend on each mobile. For this reason, I have just kept to the microphone.

Figure 9 Sleepcycle app icon

6.2 Android sleep app

The *Sleep as Android* app uses the accelerometer to monitor sleep. The charts it produces are of two types: (1) actigraphy, accelerometric movement measurement and (2) hypnograms. The first shows how much the subject moved about during the night, and the second shows what sleep phases the person went through.

Figure 10 Sleep as Android App Icon

6.3 The experiment

What was done first with the subjects was to ask them to complete a general questionnaire on their sleep (see page 41) to control factors like their diet, the amount of sport they do, how their sleepiness affects their work, and whether they consume alcohol, tobacco or caffeine on a regular basis. All these are things that can affect their sleep significantly and that would interfere with the results of the experiment if not controlled. It turned out the majority of the subjects had relatively healthy diets and did more or less regular physical exercise, as well as not consuming caffeine or tobacco on a regular basis. In any case, it was a general test to see what the overall pattern of the subjects was, and the key elements that would affect sleep more immediately (caffeine, alcohol) would be studied in more detail further on.

To do this, a second questionnaire was written for the night of the experiment (it was slightly different for each app), to see how much the subjects had used their phone that night before bed. (see Appendix 1). The two hours before they went to bed were considered, because according to other studies (Anonymous, Daily Mail, 2012) exposure to blue light will only affect sleep significantly if the exposure was for more than 50 minutes. They were also asked if they had been using any other screens for any length of time that night, and what they had been using their mobile for (gaming, texting, watching videos, social media…) to see if this affected sleep in different ways. Finally, there was also a question on whether they had consumed any alcohol or caffeine that night, once again just to make sure the results would be accurate. After the students did this test, they plugged their phone in to charge during the night, turned on the sleep monitoring app and left it near their bed.

The next morning, they were asked to send two things via WhatsApp: (1) a screenshot of their sleep graph which the application had plotted during the night, and (2) a screenshot of their battery use during the last 24h (to see what they had been using their phone for the most). It was possible to open WhatsApp on the computer via the WhatsApp Web, that is why this texting app was used: it was straightforward for the students because they use it all the time, and the images they sent could easily be analysed on the computer.

The initial goal was to carry out this experiment four nights for each subject. This was accomplished with the students from the first class, where 12 successful subjects were obtained, but it did not work out as well with the other class. It was a lot harder getting people from the other class to cooperate, as I was asking quite a lot more than most 2nd year baccalaureate students would ask of their subjects. Even so, I managed to get about 10 further people to do the test with some regularity, and others who did it just a few times. A number of these test results had to be disregarded for different technical reasons as explained below. Nevertheless, and despite these complications, in the end 52 valid night-experiments were recorded.

7. Analysing the results

Once all the data had been collected from the various experiments, it needed to be analysed. Firstly, the images received from the subjects were organized into files, dividing sleep graphs and app uses, but always keeping a way of connecting the two to the person (codes were used to preserve anonymity). Then, the information from the various paper questionnaires they had been given, both the general questionnaires and the four specific questionnaires, was organized in tables. But how to analyse the sleep graphs their phones had plotted?

This is what the sleep graph of a perfect night's sleep should look like:

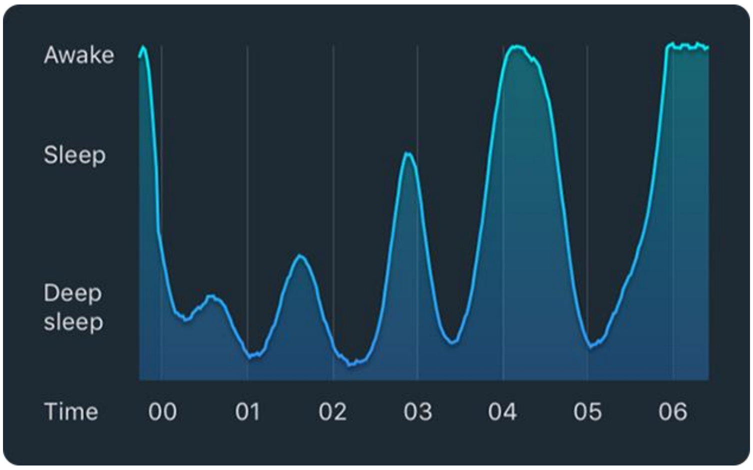


Figure 11 Graph of a perfect night's sleep

Source: Sleepcycle, https://www.sleepcycle.com/how-it-works/

The graph clearly shows peaks every 90 minutes approximately, the sleep cycles including each of the sleep phases (REM or deep sleep and non-REM or light sleep; also time awake). Also, for every sleep cycle the person goes into slightly less deep sleep.

Having such a perfect sleep graph is unusual, and some of the most typical graphs we can find are as follows:

1. Irregular sleep

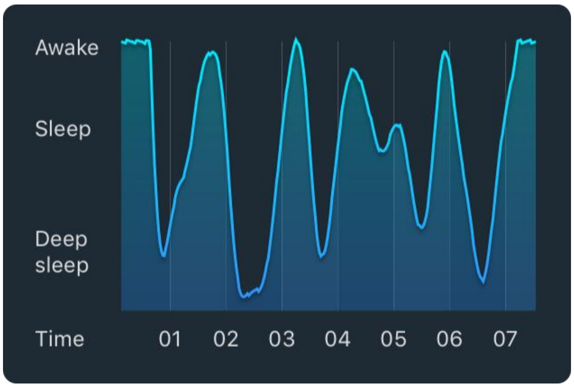


Figure 12 Graph of an irregular night's sleep

Source: Sleepcycle, https://www.sleepcycle.com/how-it-works/

Here the person took longer to fall asleep, woke up a couple of times he or she should not have, and did not have a lot of deep sleep. He or she had extended phases of lighter sleep and woke up at various points.

2. Disturbed sleep: such as when disturbed by alcohol

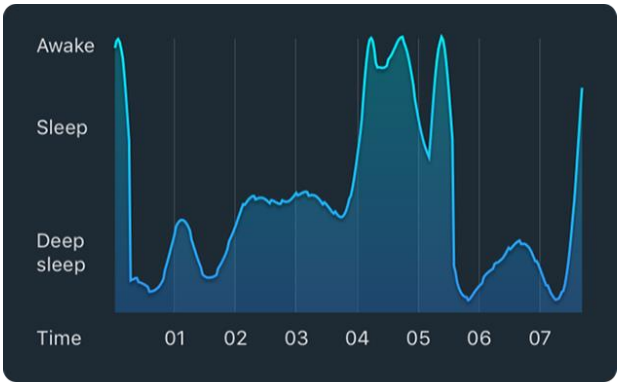


Figure 13 Graph of a disturbed night's sleep A

Source: Sleepcycle, https://www.sleepcycle.com/how-it-works/

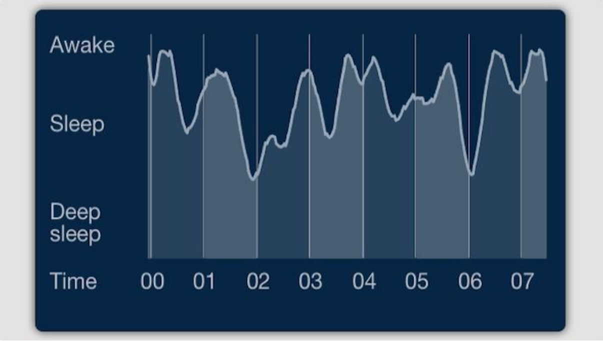


Figure 14 Graph of a disturbed night's sleep B

Source: Wareable, http://www.wareable.com/fitness-trackers/sleep-monitors-explained-more-deep-sleep

One of the deceiving things of alcohol is that it makes you fall asleep very quickly, and often (figure 13) can take you straight into REM sleep (though not always, see figure 14). Despite this, it affects sleep very negatively as the person will lose much deep sleep, wake up during the night, be restless, and no doubt wake up earlier than usual (to which we can often add the fact of having gone to bed later). The subject may be in and out of deep sleep (effect of alcohol) but will also wake up at inadequate times (see figure 13, where the person woke up thrice in a short period of time).

3. Untracked sleep

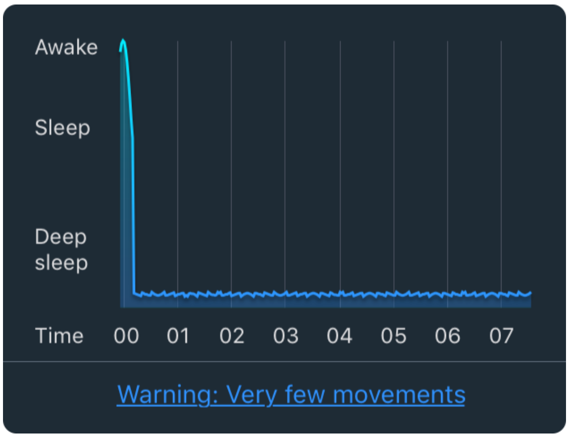


Figure 15 Graph of untracked sleep

Source: Sleepcycle, https://www.sleepcycle.com/how-it-works/

In this case the person's phone has not registered the sound of their movements during the night, and has not been able to plot a graph. Sometimes this problem can be remedied, but often the accelerometer or the microphone simply is not good enough and does not detect the movements or sounds. Unfortunately, some of the subjects in this experiment had this problem, so their results will not be useful (they have been included nonetheless).

Results

8. Answers to the General Questionnaire

The questions of the general questionnaire were as follows. As the subjects were the final year students, it was written in Catalan, and has not been translated as all those who will read this project speak and read Catalan.

==

1. De l'1 al 5, quant descanses en una nit normal?

1. No descanso gens
2. Dormo però no em desperto descansat
3. A vegades descanso i a vegades no
4. Normalment descanso, però al llarg del dia sento son
5. Descanso molt

Tingues en compte que es pot dormir moltes hores i no descansar, o dormir-ne poques i sí descansar. Si qualsevol d'aquests casos és el teu, indica-ho siusplau: ____

____

2. De l'1 al 5, amb quina regularitat fas esport?

1. Gairebé mai faig esport
2. De tant en tant faig esport lleu
3. Faig esport de forma més o menys regular
4. Faig esport diverses vegades a la setmana
5. Faig esport cada dia

3. Alimentació:

a. Quantes vegades menges al dia? (Per poc que sigui) ______

b. Com qualificaries la teva dieta? Quant a varietat i el fet de ser natural...

1. Molt pobre – menjo molt *fastfood*
2. No acostumo menjar bé
3. Alguns dies menjo bé i altres no
4. Acostumo menjar bé però hi ha alguns "buits"

5. Menjo de tot i en moderació

4. Rendiment acadèmic:

a. De l'1 al 5, com consideres que treballes (estudies) respecte a les hores que descanses?
   1. M'afecta molt la son quan treballo
   2. M'acostuma a afectar a son quan treballo
   3. A vegades tinc son a vegades no
   4. Normalment no tinc son quan treballo
   5. Mai m'afecta la son quan treballo

Si creus que aquest factor pot ser afectat per l'hora del dia en què estudies, indica-ho siusplau: ____

5. Valoracions de l'individu:

Valora de 1 a 5 (1 Res - 5 Molt) como afecta la teva son el fet de prendre cafeïna

Valora de 1 a 5 com t'afecta l'ús del tabac

Valora de 1 a 5 com t'afecta el consum d'alcohol

Valora de 1 a 5 (1 molt variable - 5 sempre igual) el teu horari d'anar a dormir

Valora de 1 a 5 (1 molt malament – 5 molt bé) como descanses habitualment

Valora de 1 a 5 (1 molt poc - 5 massa) l'ús de mòbil que fas durant el dia

Valora de 1 a 5 (1 molt poc - 5 massa) l'ús de mòbil que fas durant la nit (abans de dormir)

6. Quins altres factors creus que podrien afectar la teva son? Tingues en compte factors com l'ambient on dorms (quantitat de llum, temperatura), condicions mèdiques, estat emocional i altres. Si us plau, enumera-les des de que les que creus que t'afecten més a les que t'afecten menys.

1. –
2. –
3. –
4.

The table of the responses to these questions is on the following two pages and the results are analysed briefly afterwards.

8.1 Table 1: Responses to General Questionnaire

Subjects	Rest	Sport	Nutrition	Sleepiness and study	Caffeine	Tobacco	Alcohol	Sleep timetable	Mobile use - day	Mobile use - night
964	4	2	4	3	1	1	1	4	1	1
863	4	3	4	4	2	1	2	4	3	4
467	3	5	5	2	3	1	3	2	4	4
962	3	3	4	4	2	0	2	4	2	3
661	4	3	3	3	1	1	3	3	4	4
062	3	3	3	2	2	1	3	2	3	2
365	4	5	4	2	1	1	1	5	5	5
763	3	4	3	4	1	1	2	4	5	4
263	2	2	3	2	3	1	4	3	4	3
563	3	5	5	1	2	1	2	1	5	2
761	4	4	4	3	1	1	1	4	4	3

Subjects	Rest	Sport	Nutrition	Sleepiness and study	Caffeine	Tobacco	Alcohol	Sleep timetable	Mobile use - day	Mobile use – night
663	4	4	5	4	3	3	4	4	2	3
065	4	5	5	3	1	1	4	3	2	1
099	4	2	3	3	2	1	1	3	4	3
096	3	3	4	4	-	1	1	4	3	4
292	3	2	4	3	1	1	1	4	2	2
794	3	2	3	3	3	1	1	3	5	4
893	4	4	4	3	3	1	1	3	5	4
694	4	1	5	3	5	1	5	3	5	4
199	4	3	4	3	1	1	3	4	3	4

8.2 Some general results from the general questionnaire

Firstly, a brief comment on the data itself. Most of the responses in this table are admittedly subjective – the students' assessment of their sleep and of the impact on their sleep of different factors. But the importance of their responses is primarily to screen out subjects whose responses would be unreliable due to other external factors.

These general conclusions can be drawn from the general questionnaire:

1. All but one of these 20 students reported that they sleep at least moderately well (scores 3-5 in response to the first question). This is an interesting conclusion in itself and perhaps one that might not be expected of this age of teenagers.

2. In regards to physical exercise, 6 out of 20 reported that they do virtually none or only a little.

3. Not one student reported that their nutrition was significantly deficient (scores 1-2).

4. Only one reported significant impact of caffeine on their quality of sleep.

5. As to alcohol only 4 reported significant impact on their sleep.

6. Thankfully, crossing results relative to physical exercise, nutrition, caffeine and alcohol of this general questionnaire with the results on the specific nights of the experiments (which included questions monitoring whether they had taken alcohol and caffeine) leads to the conclusion as already explained that no subject needed to be excluded from the database of results.

7. In regards to the regularity of their bedtimes 10 out of 20 students reported that they were quite regular. However, this result does not guarantee that that regular amount of sleep is sufficient and this issue will be explored later.

8. 10 out of 20 thought they used their phones a lot or quite a lot (scores 4-5) in the evenings. This impression will be shown to be more true perhaps than the students even think.

9. Perhaps it is not surprising that only 5 students out of 20 report that tiredness normally does not affect their studies. This research project can suggest some reasons why this should be the case.

9. Android users: night tests, results and analysis

This research project involves two different mobile phone operating systems, as was explained earlier, because the apps that worked best on Android and on iOS were different: the best one for Android users was *Sleep as Android* and the best for Apple users was *Sleepcycle*. Therefore, different questionnaires were made for each operating system, and since each app produced slightly different type of data, the results were analysed separately. This, then, is the analysis of the Android users' results.

The first table is the raw data collected from the nightly questionnaires the subjects filled out, in addition to the data provided by the app: the hours they spent in bed and their percentage of deep sleep. Each subject was assigned a code number so that the experiment was anonymous: these are in the first column. The second column indicates the night of the experiment; some subjects completed the four nights of the experiment, some only handed back the results of some nights. There is a total of 10 Android users that completed the experiment at least one night, and between them all there is a total of 30 nights.

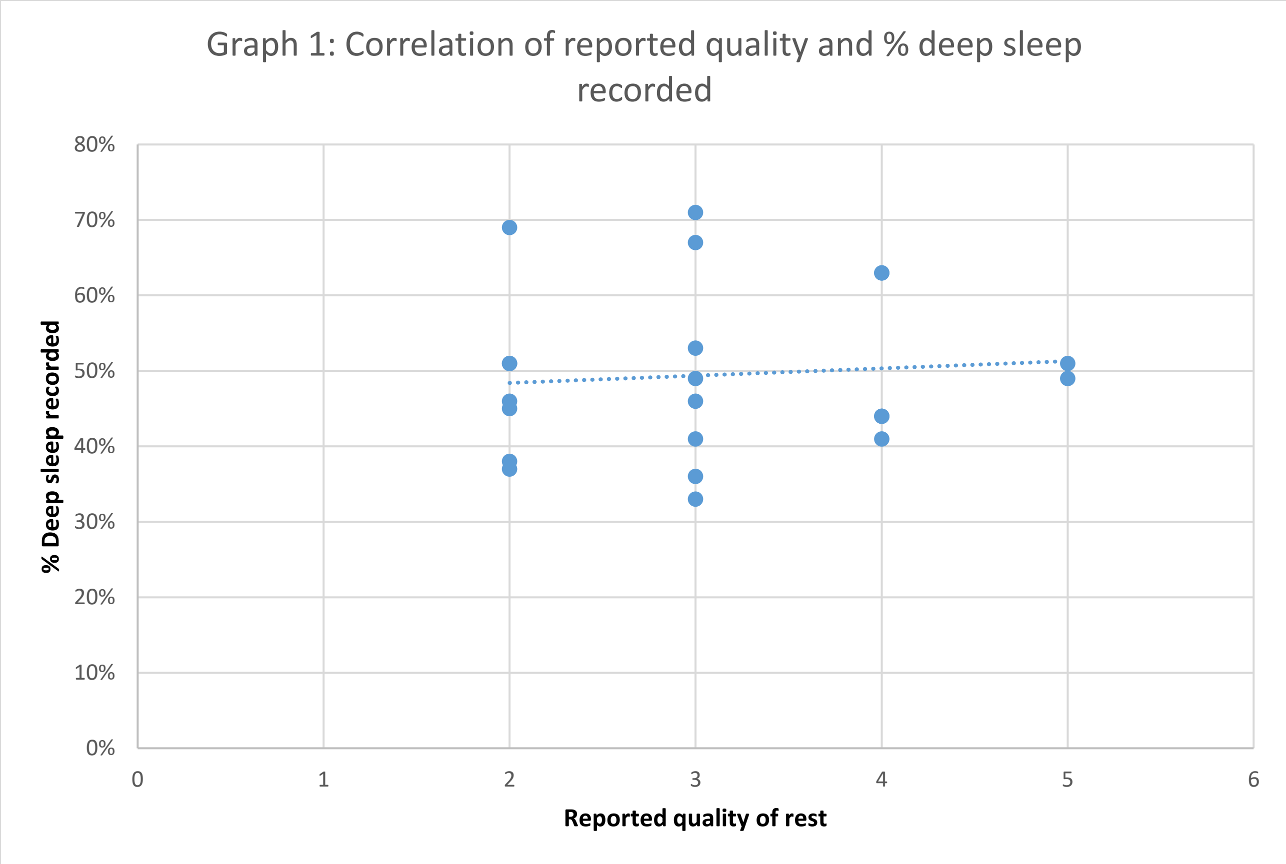
After this first (2 page) table, there are five graphs that plot different parts of the data against the percentage of deep sleep, in search of correlations. Each is then discussed, just after the table and graph, analysing the correlations in those that present them and the possible explanations in those that do not. Just as a side note, in each graph a trendline is shown to analyse the correlation between the variables. A trendline is a best-fit straight line that is used with simple linear data sets, to observe linear correlation or inverse linear correlation, in the case of this research.

After this analysis of Android users' data, we proceed to the iOS users', which will have a different analysis.

TABLE 2 Results of Sleep Tests - Android users

	Sleep tests	Caffeine/alcohol	Time with phone	Activity on phone	Time on other screen	Other factor	Bedtime	Rest	% Deep Sleep	Hours in Bed
964	Night 1	-	0min	-	1h	-	23:15		34%	7:58
964	Night 2	-	0min	-	2h	-	22:45		41%	8:32
964	Night 3	-	0min	-	1h	-	23:25		41%	7:58
964	Night 4	-	0min	-	1h	Yes	0:00		60%	7:25
962	Night 1	-	15min	Sleep app	30 min	Yes (nervous)	23:30	2	69%	6:55
962	Night 2	-	10min	Texting	2h	-	0:00	2	38%	6:36
962	Night 3	-	20min	Texting	20min	-	23:40	4	63%	7:18
962	Night 4	-	1h 30min	Texting, social media, videos	-	-	23:00	2	51%	8:13
365	Night 1	-	10min	Texting	2h	-	0:20	3	46%	6:15
365	Night 2	-	1h	Games, texting	40 min	-	23:50	2	46%	6:37
365	Night 3	-	20min	Texting, games	35min	Yes (sport)	23:50	3	33%	7:00
365	Night 4	-	10min	Texting	1h	-	23:30	2	37%	6:54
763	Night 1	-	40min	Videos, texting	1h 20 min	-	0:00	3	49%	7:02
763	Night 2	-	1h	Videos, games, texting	1h	-	23:30	3	95% - untracked	7:11

763	Night 3	-	1h 15min	Games, texting	-	-	23:45	3	97% - untracked	7:22
763	Night 4	-	1h	Games, texting	1h	-	0:00	3	99% - untracked	4:36
263	Night 1	-	1h 30min	Texting, videos	-	-	22:30	4	44%	8:44
263	Night 2	-	1h	Texting, music	1h	Yes (sick)	22:30	2	45%	7:57
263	Night 3	-	1h		1h 30 min	-	23:00	4	63%	7:57
761	Night 1	-	15 min	Texting	-	-	0:15	4	41%	7:04
761	Night 2	-	30 min	Games	1h	-	0:00	4	44%	7:15
761	Night 3	-	30min	Games	1h	Yes (sport)	0:15	5	49%	7:05
761	Night 4	-	1h 30min		30min	-	0:00	3	53%	7:20
661	Night 1	-	1h	Texting	1h 30 min	-	23:20		70%	8:02
661	Night 2	-	30min	Texting	1h 30min	-	23:30	3	67%	8:03
62	Night 1	-	Not long	Dictionary	Hours	-	2:30	3	36%	4:39
863	Night 1	-	30min	Videos, social media	1h	-	22:05	5	51%	8:56
65	Night 1	-	20min	Texting	0	-	22:35	3	41%	8:45
65	Night 2	-	5min	Texting	1h	-	23:00	3	71%	7:40
65	Night 3	-	15min	Texting, social media	-	Yes (sport)	0:00	2	51%	6:45



	Sleep tests	Quality of rest reported	% Deep Sleep
962	Night 1	2	69%
962	Night 2	2	38%
962	Night 3	4	63%
962	Night 4	2	51%
365	Night 1	3	46%
365	Night 2	2	46%
365	Night 3	3	33%
365	Night 4	2	37%
763	Night 1	3	49%
263	Night 1	4	44%
263	Night 2	2	45%
263	Night 3	4	63%
761	Night 1	4	41%
761	Night 2	4	44%
761	Night 3	5	49%
761	Night 4	3	53%
661	Night 1		70%
661	Night 2	3	67%
62	Night 1	3	36%
863	Night 1	5	51%
65	Night 1	3	41%
65	Night 2	3	71%
65	Night 3	2	51%

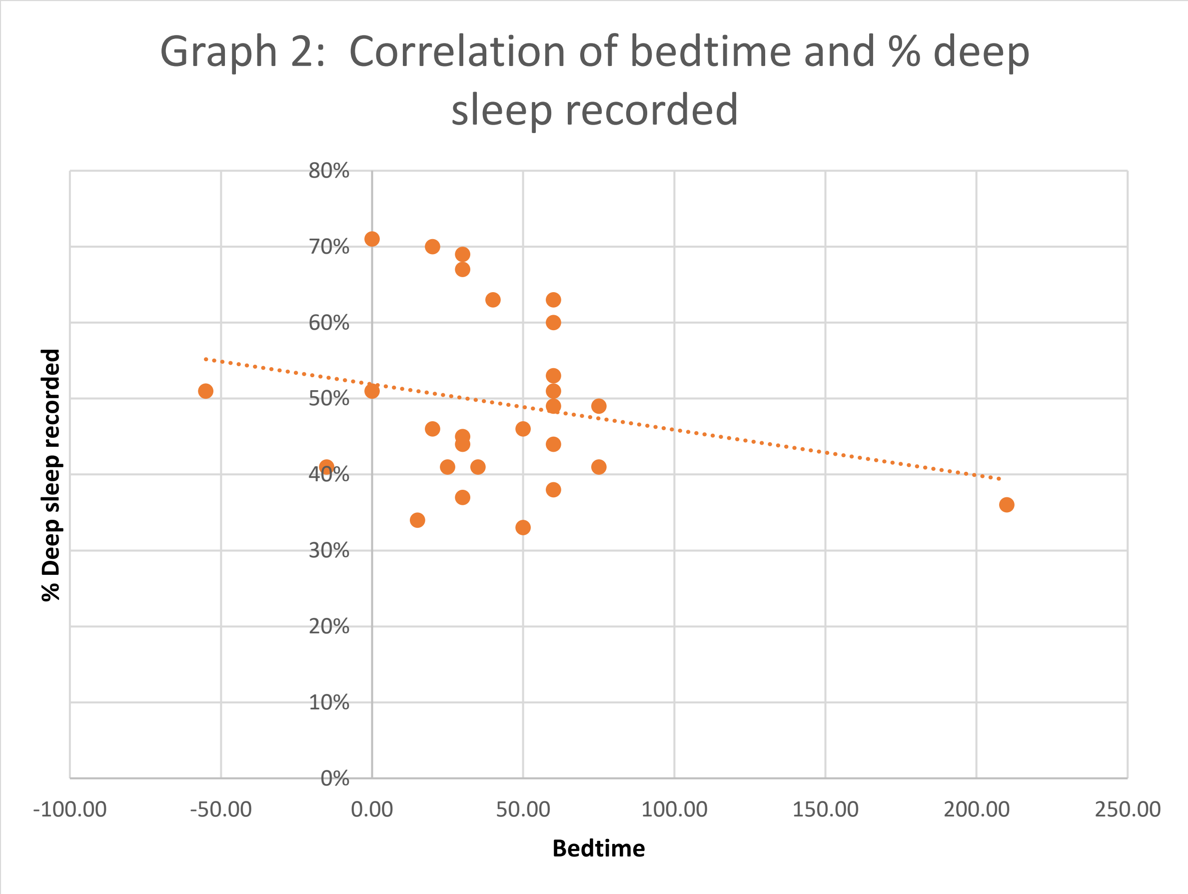
This first graph of general interest shows the reported quality of sleep the students produced against the percentage of deep sleep the app recorded. No clear correlation can be seen, as the trend line is practically horizontal. There are three possible explanations to this:

a) The subjective reporting is not a very good indicator of the quality of sleep. It is possible that the students' report of how well they slept is conditioned by their mood getting up that morning, for example. It is also true that this question was one that some of the subjects left out on the questionnaire; some of them came back to fill in later, by which time their perception of how well they slept might have changed, and some never did fill it out (see subject 964 in table 2), so there are fewer results in this aspect of the data.

b) Another possible explanation is that the app's recording of the percentage of deep sleep is not accurate. It must be acknowledged that there are studies that challenge the accuracy of these type of apps in tracking sleep. There was one in particular carried out by the Neuroscience Institute of Seton Hall University that compared the graphs produced by a different app (*Sleep Time*) to polysomnography, the graphs that track brain waves during sleep. The results of their experiment turned out to be that the app data correlated very poorly with polysomnography. On the other hand, the type of graph that the *Sleep as Android* app produces is more like an actigraph, which tracks the sleeping and awakening of the subject, and the researchers in this experiment acknowledge that it could be more useful if treated as an actigraphy instrument rather than a polysomnography one (Neuroscience Institute Seton Hall, 2015).

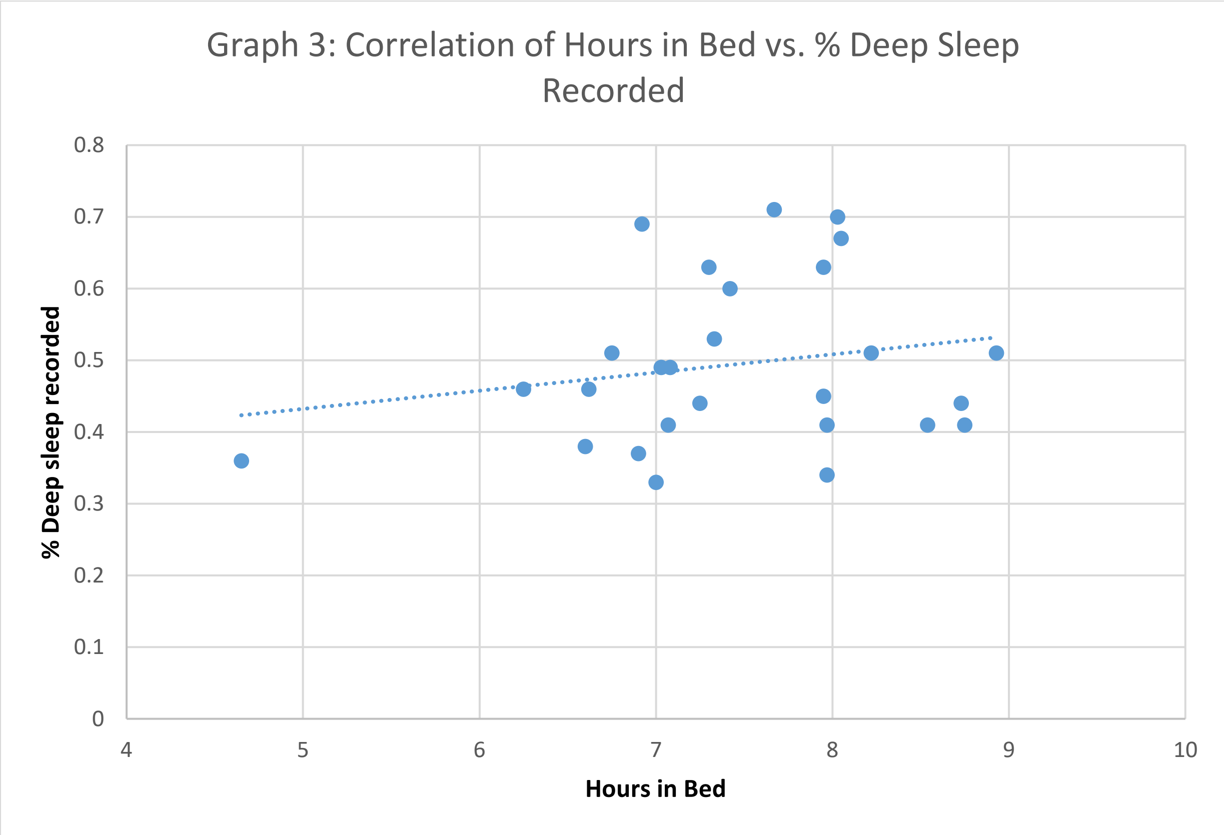
c) Thirdly, even if the percentage of deep sleep recorded by the app was accurate, it is possible that it is not such a good indicator of quality of sleep. After all, as was explained at the beginning of the research, sleep is composed of cycles which pass through different depths of sleep, including light sleep. Therefore, achieving 100 percent deep sleep in a night would not represent the ideal, best quality night.

d) It is possible that the reason for there being no correlation shown between the reported quality of the students' sleep and the percentage of deep sleep produced by the app may be a combination of some or all the factors explained above.



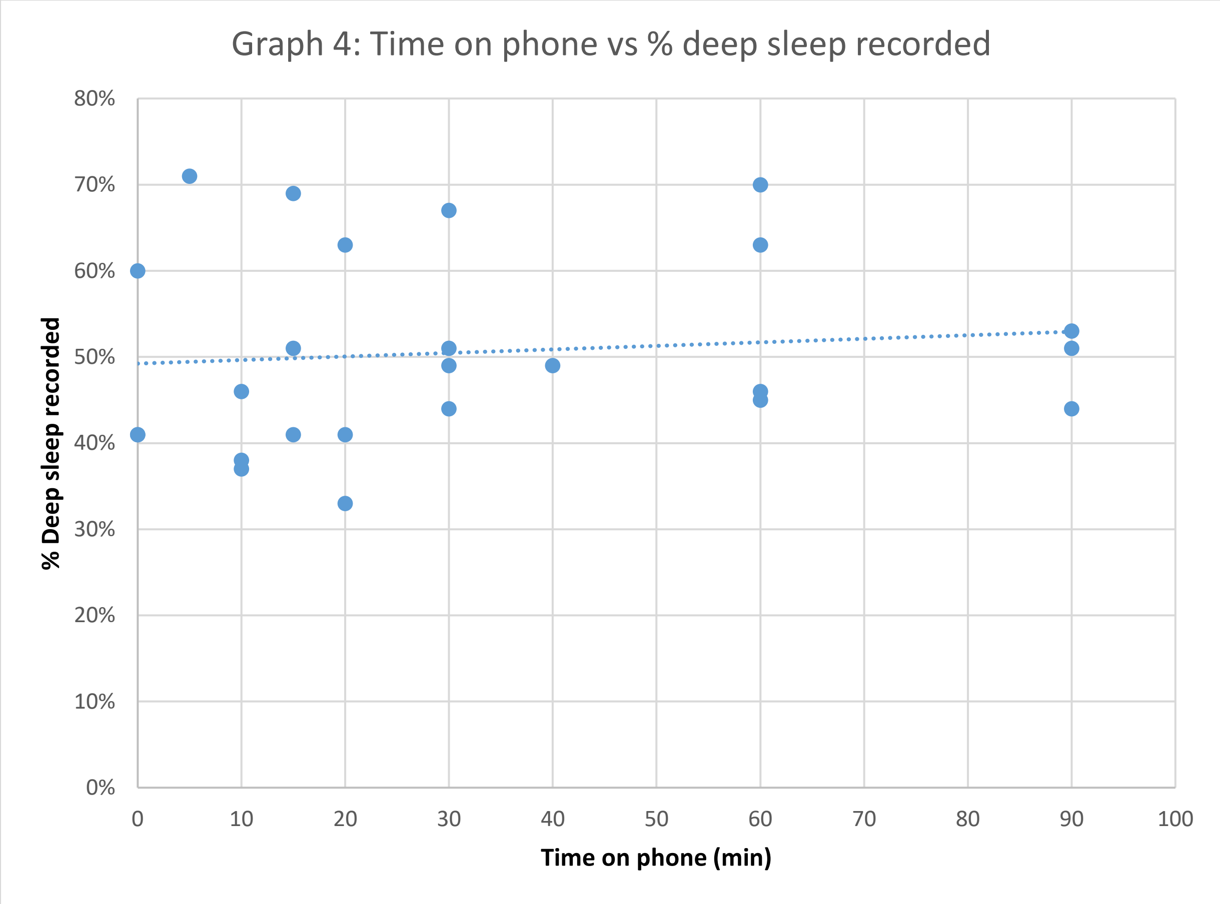
	Bedtime	Bedtime (minutes after 23:00)	% Deep Sleep
964	23:15	15	34%
964	22:45	-15	41%
964	23:25	25	41%
964	00:00	60	60%
962	23:30	30	69%
962	00:00	60	38%
962	23:40	40	63%
962	23:00	0	51%
365	00:20	20	46%
365	23:50	50	46%
365	23:50	50	33%
365	23:30	30	37%
763	00:00	60	49%
263	23:30	30	44%
263	23:45	30	45%
263	00:00	60	63%
761	22:30	75	41%
761	22:30	60	44%
761	23:00	75	49%
761	00:15	60	53%
661	00:00	20	70%
661	00:15	30	67%
62	00:00	210	36%
863	23:20	-55	51%
65	23:30	35	41%
65	02:30	0	71%
65	22:05	60	51%

This graph 2 shows clear inverse linear correlation, that is, the later the bedtime, the less deep sleep the subject experiences. This may seem common sense but nevertheless seems to be an objective demonstration of the correlation between very late bedtimes and poor sleep quality.



	Hours in Bed	Hours in decimals	% Deep Sleep
964	7:58	7.97	34%
964	8:32	8.54	41%
964	7:58	7.97	41%
964	7:25	7.42	60%
962	6:55	6.92	69%
962	6:36	6.60	38%
962	7:18	7.30	63%
962	8:13	8.22	51%
365	6:15	6.25	46%
365	6:37	6.62	46%
365	7:00	7.00	33%
365	6:54	6.90	37%
763	7:02	7.03	49%
263	8:44	8.73	44%
263	7:57	7.95	45%
263	7:57	7.95	63%
761	7:04	7.07	41%
761	7:15	7.25	44%
761	7:05	7.08	49%
761	7:20	7.33	53%
661	8:02	8.03	70%
661	8:03	8.05	67%
62	4:39	4.65	36%
863	8:56	8.93	51%
65	8:45	8.75	41%
65	7:40	7.67	71%
65	6:45	6.75	51%

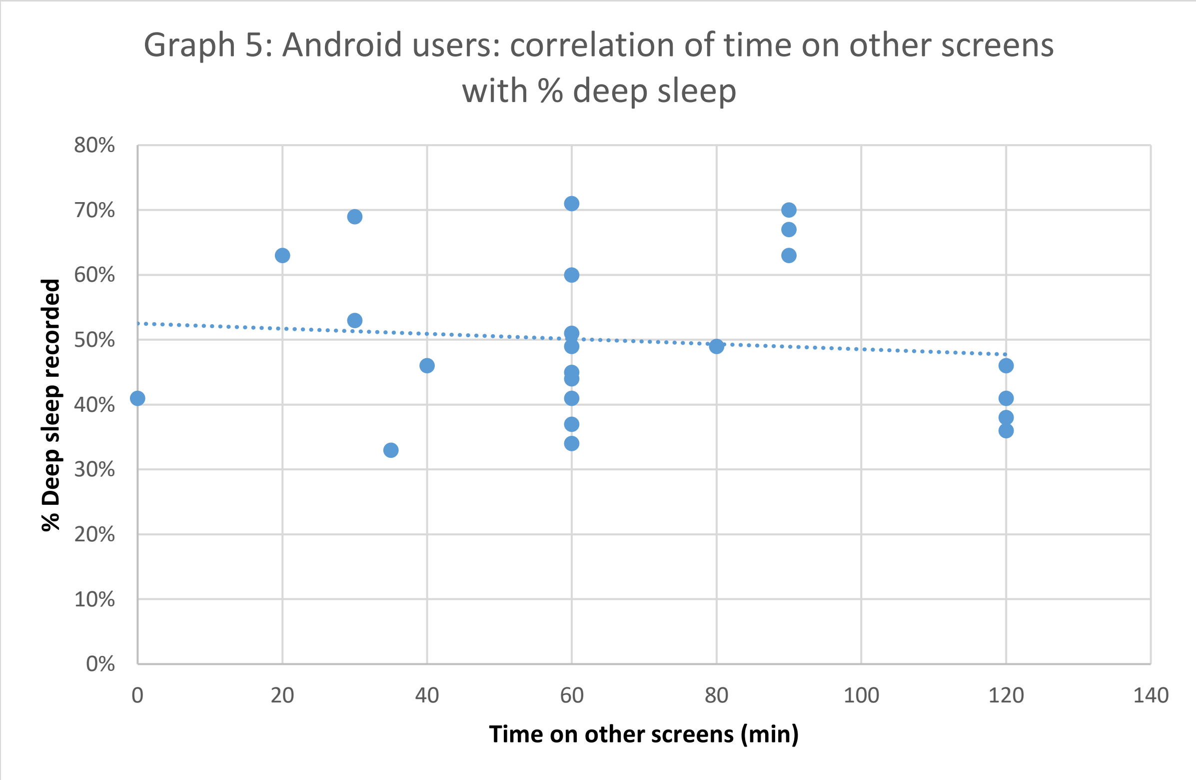
Again, in this graph 3 we find a linear correlation as might be expected, though not quite as clear as the previous graph (2). The total number of hours spent in bed (as recorded by the app) directly impacts the percentage of deep sleep.



	Time with phone in min	% Deep Sleep
964	0	41%
964	0	41%
964	0	60%
962	15	69%
962	10	38%
962	20	63%
962	90	51%
365	10	46%
365	60	46%
365	20	33%
365	10	37%
763	40	49%
263	90	44%
263	60	45%
263	60	63%
761	15	41%
761	30	44%
761	30	49%
761	90	53%
661	60	70%
661	30	67%
863	30	51%
65	20	41%
65	5	71%
65	15	51%

The results graph 4 shows are surprising. There appears to be virtually no correlation at all between the time spent on the phone and the percentage of deep sleep recorded by the app.

This is surprising given scientific studies that show that there is a strong influence of blue light from screens on sleep. One possible explanation is that blue light affects light sleep more than deep sleep, but it is a more likely conclusion that the app is not really able to provide scientific data regarding deep sleep, as was explained in the first graph (graph 1). One other thing that is important to mention is that studies show that it is only when the subject has been exposed to a screen for more than 50 minutes before bedtime that it affects his or her sleep. This is not the case for many of the people who did this experiment. Of the 25 nights plotted here, only in 7 of them did the person use their phone for *more* than 50 minutes before going to bed; all the rest were *under* 50 minutes. So perhaps it is not surprising that the overall result is that sleep was not affected by the time spent on the phone: it is because most of the subjects did not use it for long enough to show a visible impact. On the other hand, all the subjects in the experiment spend similar times with different screens and we did not have the resources to include a group in this study of individuals no using screens at all. It would have been interesting to observe subjects with that behaviour too, but teenagers that never use any screens are extremely rare and therefore it would have had to have been forced artificially somehow.



	Time on other screen	Time other screen in minutes	% Deep Sleep
964	1h	60	34%
964	2h	120	41%
964	1h	60	41%
964	1h	60	60%
962	30 min	30	69%
962	2h	120	38%
962	20min	20	63%
365	2h	120	46%
365	40 min	40	46%
365	35min	35	33%
365	1h	60	37%
763	1h 20 min	80	49%
263	1h	60	45%
263	1h 30 min	90	63%
761	1h	60	44%
761	1h	60	49%
761	30min	30	53%
661	1h 30 min	90	70%
661	1h 30min	90	67%
62	Hours...	120	36%
863	1h	60	51%
65	0	0	41%
65	1h	60	71%

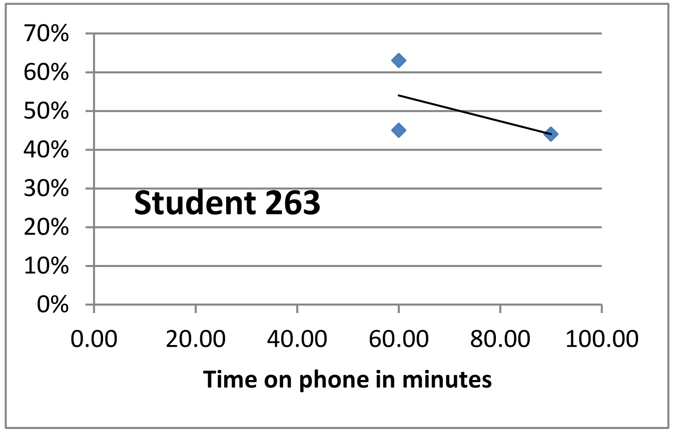
Graph 5 plots the time that the students reported using screens other than their mobile phone (mostly TV and computer but also iPad, tablet, ebook…) against the percentage of deep sleep reported by the app. It produces a result even more paradoxical than graph 4. If there is a relation, though only very slight, between these two variables it is an *inverse* one: the more time spent on these other screens the deeper they slept!

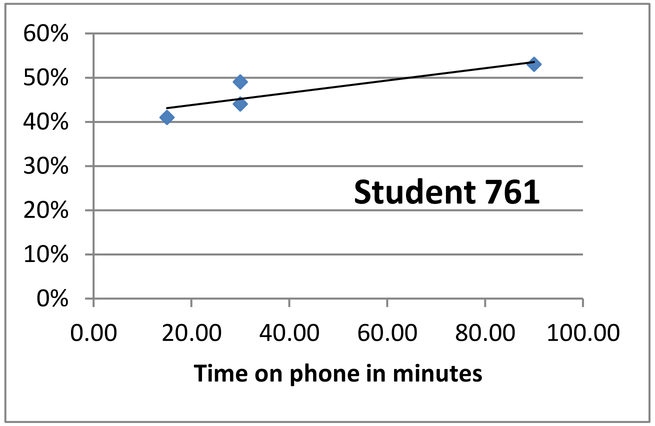
It is hard to suggest a mechanism which would explain this result given the scientific findings mentioned in the section on blue light and sleep, such as the one conducted by the Lighting Research Centre (Trafecanty, 2009). They proved that two hours' exposure to blue light could mean a 22% less of melatonin production, a severe impact on sleep. In this case, we cannot say it is because of the amount of time spent on screen because in most cases it was for an hour or more.

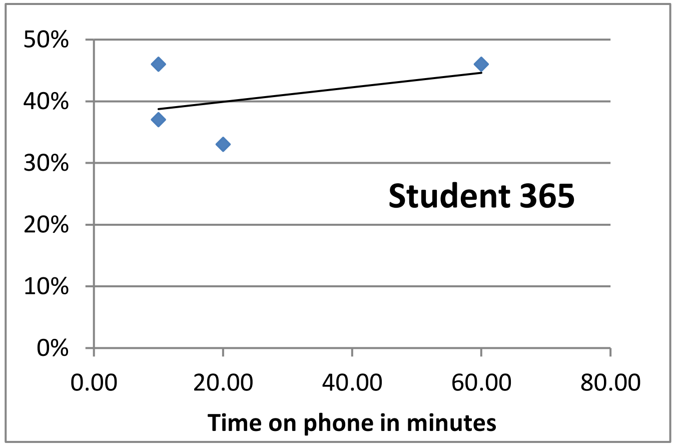
But taken together graphs 4 and 5 do lead to a clear conclusion. The app used for this experiment cannot be relied on as a source of objective scientific data, or at least not of data of real sleep. This lack of correlation between variables (time on screen and quality of sleep) is inconsistent with other scientific research as they have proved otherwise.

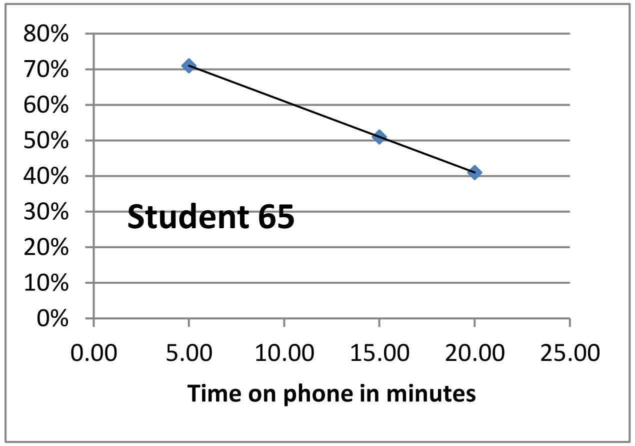
However, again these are striking sets of data in regards to the amount of time 16 to 17-year-olds from Eugeni Xammar Secondary School spend on screens, both mobiles and others, immediately before going to bed. Given the impact this has been found to have in other research experiments it is a piece of data worthy of notice. The discussion of the full impact of this point has been left until after the presentation and analysis of the iOS results.

Graphs 6,7,8 and 9: Time spent on phone vs % deep sleep for individual students









These graphs show that factors individual to each student may be playing a part as to why no correlation shows as a group between time spent on the phone and % deep sleep. For example, students 263 and 65 do seem to show the type of correlation expected.

However, detailed analysis of the available data collected was unable to explain the difference between some students and others. Averaging results showed it was not due to bedtime, hours in bed, hours on the phone, nor time spent on other screens, nor the other factors recorded in this experiment. Thus, it seems to be due to factors individual to each student and not examined in this study.

10. iOS users: night tests, results and analysis

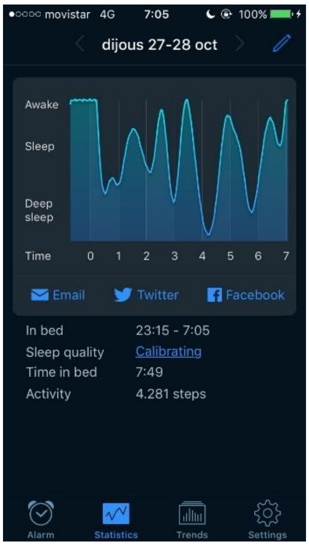
In the case of phones running iOS the graph produced by the app is presented alongside the responses to the night´s questionnaire to see if any correlations could be observed. The iOS graphs did not produce a percentage of deep sleep, only the time the subjects spent in bed. To analyse these results, each graph was compared to the examples the app producers gave (Northcube, n.d.), that is: normal sleep, irregular sleep, disturbed sleep or untracked sleep. There were also some graphs that did not fit any of these types, so they have been classified as undetermined.

	Sleep tests	Caffeine/ alcohol	Time with phone	Activity on phone	Time on other screen	Other factor	Bedtime	Rest	Hours in Bed	Interpretation of Quality of Sleep
467	Night 1	-	1min		20min	-	23:00	3	07:51	Irregular
467	Night 2	-	20min	Texting	30min	Yes (sick)	22:10	4	08:42	Irregular
467	Night 3	-	2h	Texting	30min	Yes	23:30	3	05:51	Disturbed
467	Night 4	-	30min	Texting	1h	-	22:50	3	08:06	Regular

	Sleep tests	Caffeine/ alcohol	Time with phone	Activity on phone	Time on other screen	Other factor	Bedtime	Rest	Hours in Bed	Interpretation of Quality of Sleep
563	Night 1	-	20 min		-	Yes (exam)	01:30	2	04:24	Disturbed
563	Night 2	-	0	-	1h 30 min	-	23:30		06:47	Disturbed
563	Night 3	-	30min	Texting, social media, games, videos	2h	-	00:20		05:43	Irregular
563	Night 4	-	1h 30 min	Videos	30min	-	00:15	3	05:30	Irregular

	Sleep tests	**Caffeine/ alcohol**	**Time with phone**	**Activity on phone**	**Time on other screen**	**Other factor**	**Bedtime**	**Rest**	**Hours in Bed**	**Interpretation of Quality of Sleep**
663	Night 1	-	15 min		1h 30min	-	23:45	4	06:53	(Fairly) Regular
663	Night 2	-	10 min	Texting	1h	-	23:45	4	07:00	Disturbed
663	Night 3	Yes	30min	Texting	-	-	00:10	3	06:37	Disturbed

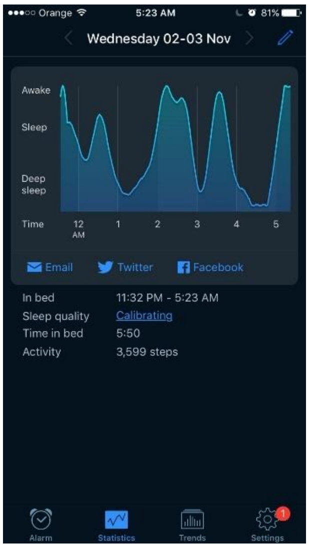
	Sleep tests	Caffeine/ alcohol	Time with phone	Activity on phone	Time on other screen	Other factor	Bedtime	Rest	Hours in Bed	Interpretation of Quality of Sleep
096	Night 1	-	Hours…	Texting, games, videos		-	00:15	5	6:39	Disturbed

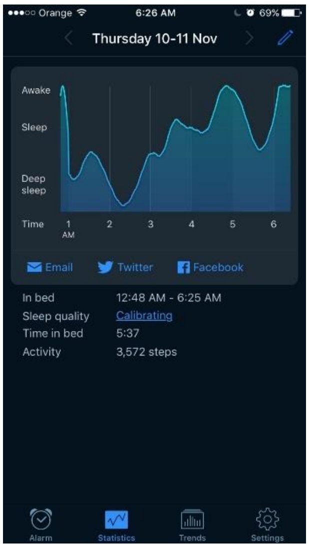


	Sleep tests	Caffeine/ alcohol	Time with phone	Activity on phone	Time on other screen	Other factor	Bedtime	Rest	Hours in Bed	Interpretation of Quality of Sleep
099	Night 1	-	30 min		45 min	Exam	00:00		7:49	Irregular

	Sleep tests	Caffeine/ alcohol	Time with phone	Activity on phone	Time on other screen	Other factor	Bedtime	Rest	Hours in Bed	Interpretation of Quality of Sleep
292	Night 1	-	Few minutes	Texting, social media	15 min	Yes (exam)	23:30	2	4:41	Disturbed
292	Night 2	-	30 min	Texting, social media	20 min	-	23:30	4	6:45	Undetermined
292	Night 3	-	45 min	Texting, social media	30 min	-	23:15	3	5:56	Undetermined

	Sleep tests	**Caffeine / alcohol**	**Time with phone**	**Activity on phone**	**Time on other screen**	**Other factor**	**Bedtime**	**Rest**	**Hours in Bed**	**Interpretation of Quality of Sleep**
893	Night 1	-	30min	Messaging, social media	1h	Yes (sick)	22:45		9:19	Disturbed
893	Night 2	-	1h	Texting, social media	3h	-	00:20	4	5:57	Regular
893	Night 3	-	10 min	Texting	-	-	23:15	3	4:44	Irregular





	Sleep tests	Caffeine/ alcohol	Time with phone	Activity on phone	Time on other screen	Other factor	Bedtime	Rest	Hours in Bed	Interpretation of Quality of Sleep
794	Night 1	-	30min	Messaging, social media	45min	-	23:30	4	5:50	Disturbed
794	Night 2	Yes	30 min	Videos, texting, social media	2h	-	00:45	3	5:37	Irregular

	Sleep tests	Caffeine/ alcohol	Time with phone	Activity on phone	Time on other screen	Other factor	Bedtime	Rest	Hours in Bed	Interpretation of Quality of Sleep
694	-	30 min	Hours…	Texting, social media	-	23:30	23:30	-	7:58	(Fairly) Regular

	Sleep tests	**Caffeine /alcohol**	**Time with phone**	**Activity on phone**	**Time on other screen**	**Other factor**	**Bedtime**	**Rest**	**Hours in Bed**	**Interpretation of Quality of Sleep**
199	Night 1	-	30 min		45 min	Yes (exam)	00:00		7:39	Irregular

11. General results regarding use of screens by Spanish teenagers

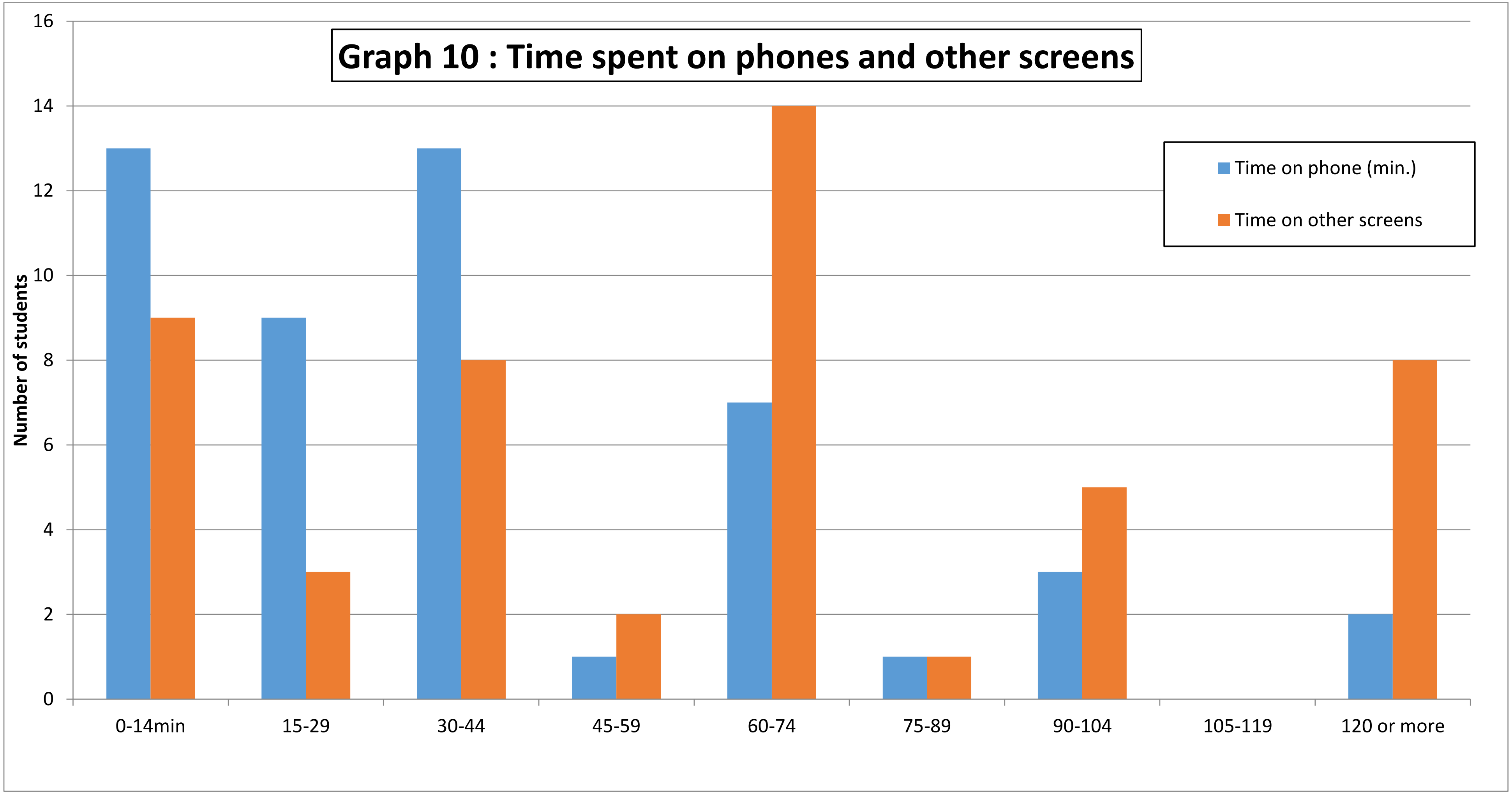
Graph 10 presents the amount of time reported by the subjects of their use of phones and other screens. As will be seen there is an interesting tailing off of the use of the phones above 60 minutes but this is offset by a significant number of subjects reporting that they were using other screens for more than that time.

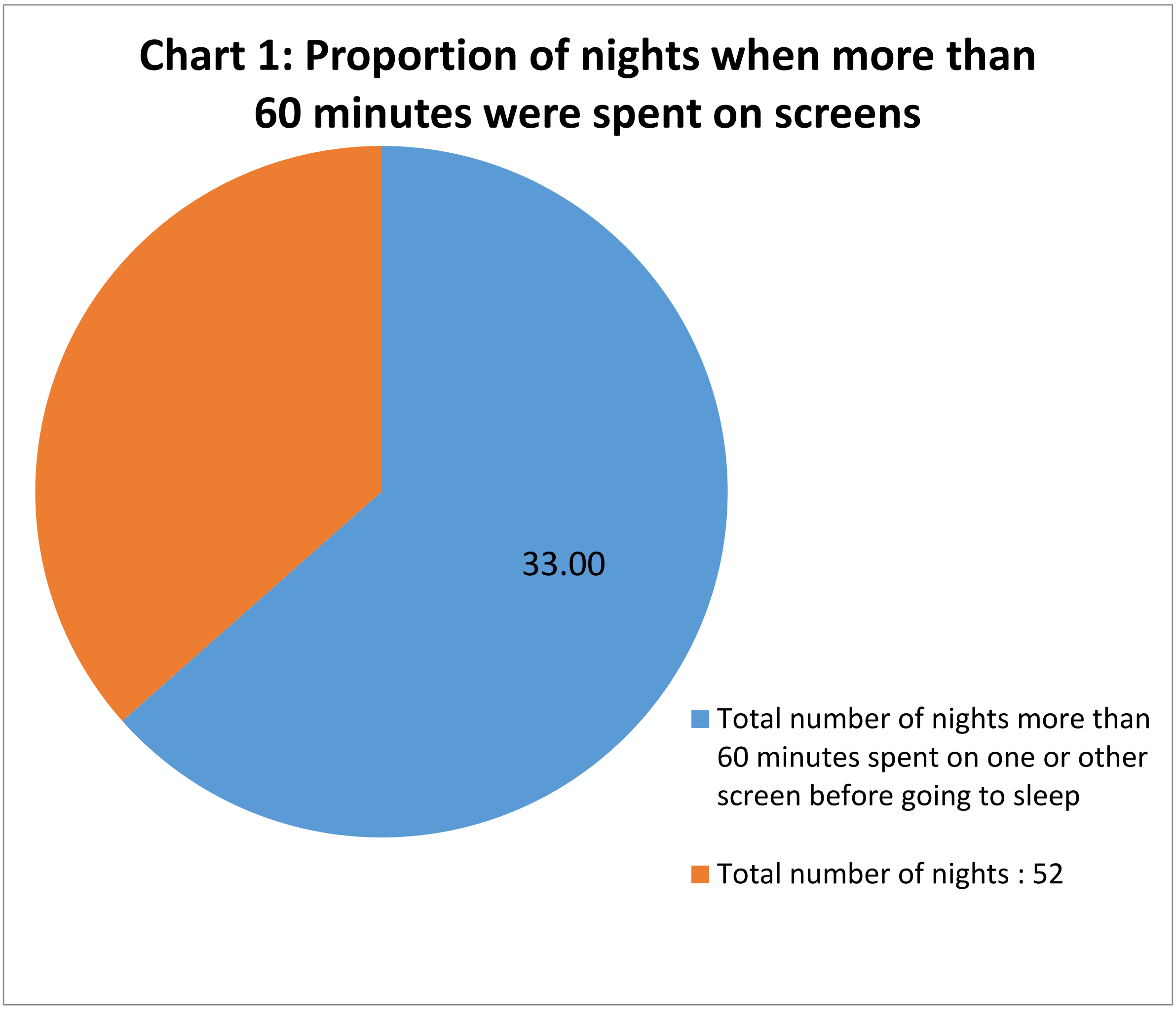
It should be borne in mind that these reported times may be overlapping. In other words, the minimum total time spent on screens is the higher of the two values (if the two screens were on simultaneously) and the maximum would be the sum of the two times (if the two devices were not used simultaneously at all). The reality will likely lie between the two.

It has been mentioned previously that there are studies that show there is an impact on sleep quality if exposure to blue light exceeds 50 minutes before going to bed (Anonymous, Daily Mail, 2012). With this in mind, if we examine the bar chart again we observe a very significant number of nights in which subjects of this experiment go to bed having exceeded 50 minutes' exposure to blue light. This is presented in pie chart 1.

As can be seen on 13 nights, subjects used their mobile phones for more than 60 minutes before going to sleep. On 28 nights, they reported using other screens more than 60 minutes. Taking both together: on 33 nights, subjects used one or other screen for more than 60 minutes. This is a huge 63% of the nights studied. Admittedly the sample is not large as the 52 nights' experiments that were performed by a total of 20 students. Nevertheless, this study suggests that a huge proportion of baccalaureate students are being affected in the quality of their sleep, and furthermore are not aware of this impact.

Remembering the answers to the general questionnaire, this excessive use of screens in the evenings seems to be a contributing factor to why only 5 out of 20 students think that they are not normally affected by tiredness in their studies. Many students are tired but are not realising that this is not merely a function of their bedtimes but also of the use of digital devices in the period immediately before going to sleep.


Graph 10 : Time spent on phones and other screens
Number of students
16
14
12
10
8
6
4
2
0
0-14min
15-29
30-44
45-59
60-74
75-89
90-104
105-119
120 or more
Time on phone (min.)
Time on other screens



Total number of nights where more than 60 minutes were spent on the **phone**	13
Total number of nights where more than 60 minutes were spent on **other screens**	28
Total number of nights where more than 60 minutes were spent on **phone or other screen** before going to sleep	33
Total number of nights	52

Conclusions

As has been clearly demonstrated by the survey of sources cited in the bibliography and analysed in the theoretical framework, sleep is a much more complex phenomenon than is commonly supposed. Though many aspects of it are not yet understood, it has a huge impact on our health and sense of well-being. A good night's sleep is characterized by many different factors.

- The percentage of deep sleep a person gets in a night is not entirely representative of the quality of their sleep on the night in question. As sleep goes in cycles, having 100% deep sleep in a night – apart from being impossible – would not be ideal nor indeed beneficial.

Conclusions in relation to the apps

- The *Sleepcycle* and *Sleep as Android* apps are not scientifically accurate, due to the lack of correlation between variables that other previous research has shown to be related. This can be seen particularly in graphs 4 and 5 comparing the time spent on the mobile phone and the time spent on other screens with the percentage of deep sleep. Specifically, it is possible that the percentage of deep sleep recorded is non-scientific and inaccurate data. The inefficiency of the app may have affected the results of the experiment, although other factors are discussed in the analysis of graphs 1, 6, 7, 8 and 9. In any case, these apps do not seem to be scientifically reliable.

Conclusions in relation to perception of quality of sleep

- One's perception of his or her quality of sleep is not always accurate. The subjective element of this research will likely have impacted the results of the experiment, not only on the reported quality of sleep, but also the times spent on both mobile phone and other screens. This can be seen in the results of graph 1, where no possible correlation was found between the students' report of how well they slept and the percentage of deep sleep.

- In the general questionnaire, only 5 students reported significant impact of alcohol (4) or caffeine (1) on sleep, although it is very well known that these factors impact sleep significantly. Either they are unaware of the extent of its impact, or they possibly consume them less during term time.

- Also from the general questionnaire, 10 out of 20 students reported sleeping moderately or very well (4-5 out of 5), but this research shows that 63% of them spend large amounts of time on screen before going to sleep, meaning they do not sleep as well as they should.

Conclusions in relation to the sleep patterns of teenagers

- Length of time spent in bed directly impacts depth of sleep. The fewer hours a person spends in bed, the less deep sleep they will get that night. The average amount of time subjects spent in bed was 7:03 hours, and this is evidently lower than the recommended amount.

- Bedtime directly impacts amount and depth of sleep. The later a person goes to bed, the less deep sleep they will get that night. In relation to this point it is particularly interesting to note that 10 out of 20 students reported regular bedtimes, but it is likely that these betimes were too late (the average was 23:42), and their sleep was affected by this.

  There could be a million explanations of why the subjects went to bed as late as they did, but there are two worthy of mention. The first is if there are exams the following day, as it is a common habit among secondary students to stay up very late or get up very early to prepare for these. The second is related to screens: it is possible that the use of screens indirectly impacts sleep by making the subjects go to sleep later than they would have done otherwise.

Conclusions in relation to the impact of screen use on sleep

- Surprisingly, the heaviest use of screens was not of mobile phones, but of others such as TV, computer, tablet etc. These also emit blue light, as mobiles do, and therefore have their own effect on sleep.

- *Batxillerat* students spend large amounts of time exposed to blue light in the evening. 63% of them spend more than 60 minutes on their mobile phones or on other screens at night. This is above the threshold of 50 minutes at which there is significant impact on sleep.

Perhaps the most significant conclusion is that these teenage students seem totally unaware of the impact of screens on their sleep, and do not attribute poor quality of sleep to an unhealthy exposure to blue light. All but one of the students that took part in the experiment affirm that they sleep at least moderately well, although this study has shown that the vast majority of them are being impacted by their use screens at night. Therefore, we can say that the hypothesis is proved in relation to screen use in general, not just mobile phones. If a teenager spends more than 50 minutes exposed to blue light screen before going to bed, then they will sleep less deeply than one who has not.

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Appendices

Appendix 1: Individual Night Questionnaire

As with the General Questionnaire, it has just been left in Catalan as all those who read this Research Project will understand the language.

iOS

Fes aquest test ràpid just a l'hora d'anar a dormir:

1. Has pres cafeïna o alcohol aquesta nit?

2. De les dues hores d'abans d'anar-te a dormir, quant de temps has estat amb el mòbil? Per a què l'has fet servir? (missatges, jocs, vídeos...)

3. Has fet servir alguna altra pantalla en les últimes dues hores? (Televisió, ordinador, tablet, ebook...) Quant de temps?

4. Ha passat alguna cosa avui que et descol·loqués emocionalment (no cal especificar), o hi ha alguna altra cosa que creus que t'afectarà la son d'avui?

5. A quina hora te'n vas a dormir avui?

6. Si us plau, envia una captura de pantalla de l'ús de la bateria del teu mòbil de les últimes 24 h a 628 658 394 (Noemí Reid) → (Ajustes, bateria)

7. Recorda't de engegar l'aplicació *sleepcycle*, endollar el mòbil i deixar-lo al costat teu al llit (pots posar-lo en mode avió si vols).

Endemà al matí: envia al mateix número una captura de pantalla de la teva gràfica de son que ha registrat l'aplicació. De l'1 al 5 (molt poc – 5 molt), quant has descansat avui? ___

ANDROID

Fes aquest test ràpid just a l'hora d'anar a dormir:

1. Has pres cafeïna o alcohol aquesta nit?

2. De les dues hores d'abans d'anar-te a dormir, quant de temps has estat amb el mòbil? A quina hora? Per a què l'has fet servir principalment? (jocs, vídeos, missatges...)

3. Has fet servir alguna altra pantalla en les últimes dues hores? (Televisió, ordinador, tablet, ebook...) Quant de temps?

4. Ha passat alguna cosa avui que et descol·loqués emocionalment (no cal especificar), o hi ha alguna altra cosa que creus que t'afectarà la son d'avui (esport intens per exemple...)?

5. A quina hora te'n vas a dormir avui?

6. Si us plau, envia una captura de pantalla de l'ús de la bateria del teu mòbil de les últimes 24 h a 628 658 394 (Noemí Reid) → (Ajustes, bateria)

7. Recorda't d'engegar l'aplicació *Sleep as Android*, endollar el mòbil i deixar-lo al costat teu al llit (pots posar-lo en mode avió si vols).

Endemà al matí: envia al mateix número una captura de pantalla de la teva gràfica de son que ha registrat l'aplicació. De l'1 al 5 (1 molt poc – 5 molt), quant has descansat avui? ___