THE AFFECT OF THE USE OF BEDTIME TECHNOLOGY

ON

THE BODY'S CIRCADIAN RHYTHM

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A Research Project

Presented to

CREST (British Science Association)

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In Partial Fulfilment

of the Requirements for the CREST

Gold Award

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by

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January, 2020

STATEMENT OF ORIGINALITY

I, Montgomery-Everard Edward John Lord of St. Joseph's RC High School, Horwich, Bolton, being a candidate for the CREST Gold Award, hereby declare that this research project and the work described in it are my own work, unaided except as may be specified in the text, and that the research project does not contain material that has already been used to any substantial extent for a comparable purpose.

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- I have not falsified, embellished or manipulated any data.
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ABSTRACT

Sleep is imperative to the proper functioning of all animals and greatly affects such things as health, behaviour and cognitive functioning on a day-to-basis. Sleep itself is governed by the body's circadian rhythm which is essentially a sleep/wake cycle.

Children are one of the largest consumers of technology.

The purpose of my CREST research project is to identify the affects of bedtime technology on the body's circadian rhythm.

My study focuses on adolescents with the hypothesis that using bedtime technology at night will adversely affect their circadian rhythm, leading to reduced sleep duration, delayed sleep onset, reduced daytime attentiveness and anxiety disorders.

Adolescents spend increasingly more time using bedtime technology, and sleep deficiency rising in adolescents constitutes, I believe, a major public health concern.

ACKNOWLEDGEMENTS

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CONFLICTS OF INTEREST

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this research study.

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INTRODUCTION

Children are one of the largest consumers of technology.[1]

Children, adolescents, kids, youths, young people, call them what you like, they have all grown up using technology so readily, it's almost an extension of the body. Children can be classed as '*digital natives*'. We live in an attention economy with so much information being processed and ignored on a daily basis that the quickest way to absorb this is digitally.

On 5th August, 2010, the then CEO of Google, Eric Schmidt, stated that every 2 days we create as much information as we did in the time period between the dawn of civilisation up to 2003. He stated this was around five exabytes of data, every 2 days.[2]

This digital environment has led to an increase in the amount of time that children spend using digital screens and other forms of technology. Some schools even require their students to submit homework via digital devices, some issuing iPads and tablets for that very purpose. This increase in screen time is all part of modern education.

The portability of technology coupled with the drive for more compact devices that have multi-functions, has led to a dramatic rise in the use of mobile phone technology amongst adolescents.

The technology that we have today, being of a 24-hour nature, has brought the entire world closer together, enabled communication and provides information on-tap at a moment's notice. This has created a societal addiction to information and the need to remain constantly connected to one another.

Alongside this rise in the use of technology during bedtimes, is the problem that adolescents get fewer hours of sleep during weekdays and this affects their abilities during the daytimes both inside and outside the school setting.

Some studies have shown that a reduction in sleep or sleep disturbance has other consequences including long-term health affects to motor development, weight gain, cognitive functioning, increased addictions to caffeine and nicotine and even suggestions of cancer growth.

Although the various mechanisms that affect circadian rhythms have remained similar throughout history, it's only in recent times that technology has started to play its part and the things that accentuate these mechanisms are related to what we term, '*zeitgeist*.' The Oxford English Dictionary defines zeitgeist as, "…*the general mood or quality of a particular period of history, as shown by the ideas, beliefs, etc. common at the time*." These are things like societal, cultural, technological and general lifestyle trends that occur within each era.

There is already a wealth of research covering different age demographics and some indicating a causal link between night time technology use and daytime sleepiness. These studies aren't confined to the UK. Research has been undertaken in many countries around the world.

The aim of this research study is to see whether it can be established through empirical study of a statistically significant-sized data sample, that bedtime technology has an affect on circadian rhythms. In this study I have focused on 3 core areas: i) Sleep; ii) Bedtime technology and iii) Circadian rhythms.

SLEEP

Sleep is very important for the optimal day-to-day functioning of all animals. Sleep is crucial for us to survive,[3] especially during the developmental years of childhood and adolescence.[4]

According to a survey by The Sleep Matter Club, part of the Dreams group, humans spend, on average, 26 years of their life asleep.[5]

Without adequate sleep, cognitive functioning can not operate normally. The natural result of this will be an adverse impact on academic performance in schools by adolescents. [6-10]

Sleep patterns are just as important, if not moreso, to the body's circadian rhythm, than the actual duration of sleep. This daily pattern of sleep directly correlates to a person's health, wellbeing and general moods.[11,12]

It is well-documented throughout various studies, that sleeping is a necessary requirement for optimal cognitive and physical functioning.[13,14]

It is believed that regular disturbances to an adolescent's sleep cycle might increase the risk of physical and mental issues.[15]

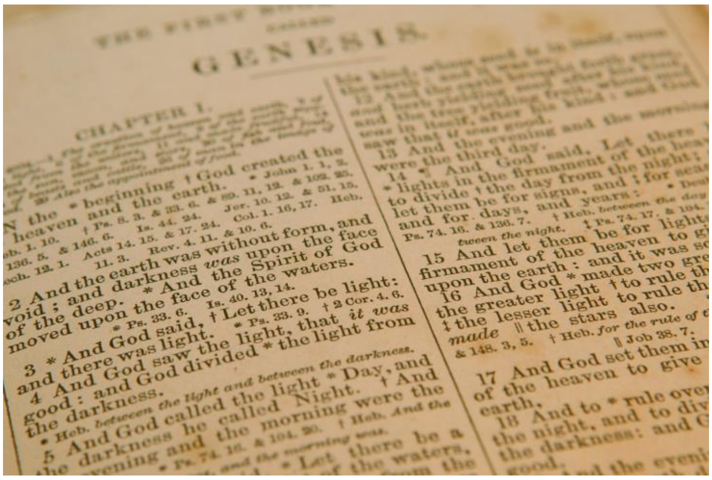
Sleep deprivation among adolescents has probably always occurred due to the hormonal influence within the body for that age demographic. It is, however, only within the last few decades, that scientists and clinicians have turned their attention towards it.[16]

Although the modern clinical studies into sleep and circadian rhythms have only really occurred since the 1950's, it's clearly been an area of interest for many centuries. Whether a believer in divine creation of the Earth and humankind or whether you're an atheist or of agnostic belief, the fact is, many religious texts are historic documents and provide clear evidence that sleep was of interest to us centuries ago.

There are many references to all aspects of sleep within the Bible and the Jewish Talmud.[17]

The first mention of sleep in The Bible can be found in the Book of Genesis, which states, "*And the LORD God caused a deep sleep to fall upon Adam, and he slept: and he took one of his ribs, and closed up the flesh instead thereof*" (Genesis 2:21).

There are also several references in The Bible to various dream states. Genesis 28:11-15 refers to the dreams experienced by Jacob. Genesis 41:25–32 refers to the dreams experienced by Pharaoh.



The Bible goes further stating that sleep can be seen as a gift from God. In Psalms 127:2, it states, "*…for so he giveth his beloved sleep.*"

Greek literature refers us to the account of Dionysius, the tyrant, who, through being so fat and suffering with sleep apnoea, he had to be awoken daily by an appointed person pricking his body with very long and sharp needles.[18]

The 19th century novelist Charles Dickens has provided what may been considered as the first literary account of sleep disorders in his very first novel, *The Pickwick Papers* (The Posthumous Papers of the Pickwick Club*)*.[19] Dickens describes symptoms related to sleep apnoea in his character 'Joe the fat boy.'

Today's generation of adolescents sleep fewer hours, have more irregular sleep patterns and experience more symptoms of daytime sleepiness as compared to previous generations of adolescents.[20,21]

When a person goes through adolescence, both their attitude to sleep & general sleep architecture undergoes several changes. They sleep fewer hours, tend to go to sleep later in the night (a term referred to as '*eveningness*') and in general, their sleep doesn't seem to be as deep in nature. This is all due to several factors that influence adolescent behaviour and sleep cycles. These influences can be broken down into external and internal influences which play their part in affecting the daily circadian rhythm. [22]

External influences are things like school times and other fixed diarised events which necessitate waking up at specific times. These tend to force adolescents to cut short their sleep, certainly earlier than they'd prefer. At the opposite end of the sleep period are things that influence adolescents to remain awake each night until much later. These are things like using technology or scheduling of television programmes, even some medical conditions necessitating frequent visits to the bathroom during the early stages of the night.

Internal influences are things like the hormonal or protein imbalances in the body which accumulate over a daily cycle.

During a school week, when adolescents are exposed to both these internal and external influences, they will stay awake until later and are forced to awaken earlier during the day. These levels of insufficient sleep create a situation whereby the adolescent will accumulate '*sleep debt*' over the period of the week. This sleep debt has to be balanced out and so accordingly, during most week-ends or school holiday periods, adolescents will tend to remain in bed and/or sleep for extended periods of time, compared with normal weekday sleep times.[23]

The current recommended sleep guidelines for adolescents in the UK from the NHS (as recommended by the Millpond Children's Sleep Clinic)[24] are:

- **11 years:** 9 hours 30 minutes
- **12 years:** 9 hours 15 minutes
- **13 years:** 9 hours 15 minutes
- **14 years:** 9 hours
- **15 years:** 9 hours
- **16 years + :** 9 hours

In the USA, the current recommended sleep guidelines for adolescents, issued by The National Sleep Foundation (NSF)[25] are:

- **6 - 13 years:** 9 hours – 11 hours
- **4 - 17 years:** 8 hours – 10 hours

In 2014, the National Sleep Foundation in the Unites States of America, conducted a subjective sleep survey, referred to as, '*Sleep in the Modern Family*'[26] in order to determine the sleep habits of American families with at least one school-aged child. They surveyed approximately 1,100 parents with children aged in the 6-17 years old demographic. The survey looked at the bedtime routines and the sleep patterns of the parents themselves and their children. 90% of the parents responded to say that they felt that sleep was important for their family's health. Interestingly, 90% of the parents also responded to say that their children slept less than the recommended guidelines. The parents identified that one of the main reasons their children remained awake later was due to their use of bedtime technology (electronic devices) during the night.

- **<u>The science of sleep</u>**

Today's studies into the field of sleep medicine began in the early 1950s. Around this same time, Rapid eye movement (REM) sleep was also discovered along with the fact that sleep is not solid and consists of several phases or 'stages' as they're known.[27,28] These stages are distributed throughout the sleeping period in a cyclical pattern, reoccurring several times throughout a person's sleep. A lot of clinical research has been conducted over the seven decades to advance our understanding of the etiology of sleep patterns and the sleep cycle.

It’s important to also keep in mind that sleep disorders have existed and have been documented long before the initial foray into sleep medicine in the early 1950’s.

Studies have shown a statistical correlation between sleep debt in adolescents and depression, mental health disorders, lethargy, reduced productivity and poor school performance.[29,30]

We’ve already briefly considered external & internal factors that exert influence over adolescent sleep patterns, compounding these factors are the modern-day technological advancements and zeitgeist factors like societal, socio-economic, fashion and other popular activities of the day. These influences actively engage and arouse the mind of adolescents, encouraging their later sleeping times.[31-33]

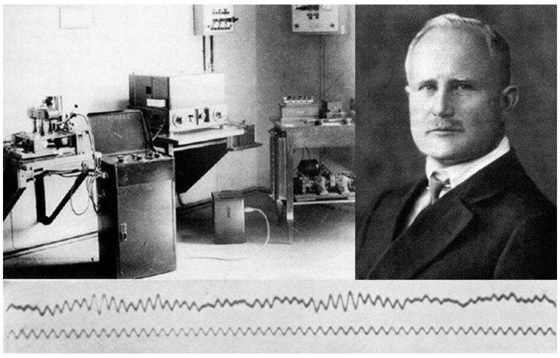
Other such factors depend upon the individual’s lifestyle choices and include things like: levels of anxiety when detached from technology, the need to remain socially connected with their friends, weight gain issues, caffeine, alcohol & nicotine addictions.

- **Sleep cycle**

Whilst we sleep, our heart rate and body temperature decrease and our brains undergo significant changes in brain wave activity. This produces the varying stages of sleep that our bodies undergo on a daily basis. It's a cyclical event, hence the term, '*sleep cycle*.'

Since the discovery of REM sleep in 1953, clinical studies have been using the electroencephalogram (EEG) which measure electrical currents from the human brain, to provide insights into the brains electrical activity whilst we sleep.

Interestingly, it was Hans Berger (1873-1941) who developed the EEG, initially as a means of trying to uncover the scientific basis of telepathy.



Hans Berger – developer of the EEG

To have peaceful and undisturbed sleep, a sleeper must go through the four stages of the sleep cycle and generally complete several sleep cycles per period of sleep. These four stages are split into Non-REM (NREM) sleep and REM sleep. REM stands for '*Rapid Eye Movement*.'

Stages 1 to 3 are in the NREM phase of the cycle, with stage 4 being the REM sleep phase. The sleeper can also undergo momentary periods of wakefulness or mobility of their sleeping position in bed, both before and during the various NREM & REM sleep stages.

Usually a sleeper will progress through the 4 sleep stages in a cycle, moving from stages, 1 to 2 to 3 and finally onto the REM stage, before returning to the 1st sleep stage once again. Each iteration of this sleep cycle lasts on average between 90 and 120 minutes, resulting in around four to five cycles each period spent asleep. The first sleep cycle lasts approximately 90 minutes, with each subsequent cycle lasting progressively longer.

Delving into the various stages of sleep, we first look at Stage 1 of NREM sleep. This is the first stage of sleep and notably the lightest sleep that a sleeper experiences. It's almost like a light, drowsy sleep, when you first doze off. The sleeper will still be quite alert to goings-on around them and very able to be roused or have their sleep disrupted.

Stage 1 sleep phase is signified by slow movements of the eyes and a gradual relaxation of muscles in the body. At the same time, the sleeper's brain waves will start to slow down. Rarely, the sleeper may also experience slight muscular spasms, known as *hypnic jerks*.

The next stage, the second stage of sleep, marks a more defined move into the NREM phases of the sleep cycle. This is what we'd imagine to be proper sleep as opposed to just a light doze. This second stage of sleep lasts for longer than Stage 1, generally consisting of 40-60% of the overall sleeping time.

Whilst a sleeper can still be awoken in this stage, it is a lot harder to be roused from sleep compared to a sleeper in Stage 1 of NREM.

This sleep phase is signified by a discontinuation of the eye movements and a reduction in both core body temperature and heart rate. This is accompanied by a marked change in brain wave activity where a mixture of slow and rapid brain waves, known as sleep spindles and K complexes. The prevailing belief is that these *sleep spindles* and *K complexes* are a mechanism by which the brain protects itself from sudden awakening.

The third stage, Stage 3 of NREM sleep is known as the '*deep sleep*' phase of the sleep cycle. It's far less common to be awoken with disrupted sleep in this stage and it's also quite hard to awake a sleeper from deep sleep. It is in this stage of sleep that many of the night-time sleep disturbances can occur, for example, sleep walking, talking in one's sleep, knee jerking, night terrors, etc.

This phase of sleep is signified by another change in brain waves as they slow down and increase in amplitude even further, into what are known as *delta waves*. Of all the sleep stages, this deep sleep phase is known to be the most restorative and deep sleep recovers the body from excessive sleep debt. It is for this reason that if you take a nap during the daytime and oversleep, your body basically cancels the sleep deficit and you can struggle getting to sleep later that same day.

During this Stage 3 of NREM sleep, human growth hormone (HGH) is released which helps to restore the body along with the immune system. This third stage of the NREM sleep cycle doesn't last as long as Stage 2. Although in adolescents, Stage 3 has a much longer duration than in adults.

The fourth and final stage of the sleep cycle is the REM sleep phase. This REM phase is often referred to as the '*dream*' stage of sleep. This is characterised by rapid eye movement, hence the REM name. In this stage, whilst the eyes are rapidly moving, the brain waves show a marked rise in activity, certainly from the previous sleep stages of brain waves. Heart rate, breathing rate and blood pressure all increase and legs and arms remain immobile, almost in a paralytic state.

As with Stage 1 of the sleep cycle, it's relatively easy for the sleeper to be awoken during REM sleep. The one drawback, however, is that after being awoken in this stage of the sleep cycle, the sleeper can experience what is known as '*sleep inertia*' where they will feel very sluggish for the rest of the day.

The 4 stages of sleep [34]

So in effect, the sleep cycle is a progressive cycle of the sleeper moving through the stages of NREM sleep where their body moves from a state of wakefulness to deep sleep and eventually back into a lighter sleep, at which point they will enter the REM sleep stage approximately 90 minutes following the onset of sleep.

During the initial sleep cycles, the REM period is a relatively short-lived stage, whereas the stage 3 NREM (deep sleep) cycle is longer earlier on in the overall sleep period. Towards the end of the overall sleep period, the REM sleep stages increase in duration and the deep sleep stage decreases. After the sleeper experiences REM sleep, their body once again progresses through the sleep cycle, starting back with stage 1. This is why there can often be periods of wakefulness during a person's sleep with plenty of movement in the bed.

That's the model of the *Sleep Cycle*. However, the reality is that the sleeper can progress through the 3 NREM stages of sleep in a random manner, perhaps even moving straight from Stage 1 to Stage 3. The sleeper will usually go through between 3 to 5 cycles of REM sleep during each overall sleep period. Whereas quite often a person will awake and only recall one dream, they have most likely had multiple dreams throughout that period of sleep but only recall the most recent, just prior to waking.

Dreams themselves are incredibly important and considered by psychoanalysts to be part of the body's recuperation process. Sigmund Freud (1856-1939), an Austrian neurologist and the founder of psychoanalysis, discovered the importance of interpreting dreams. In his book, 'The Interpretation of Dreams' (1900), he considered dreams to be what he called the, '*royal road to the unconscious*'. Freud surmised that dreams come about as a result of the occurrences and experiences a person has on a daily basis. Without sleep, there can be no dreams.

Previous experimental studies have established just how important sleep is to memory consolidation, learning and cognitive development,[35,36] especially during the

Stage 3 NREM (deep sleep) phase where the brain replays the activity and information absorbed during the period of wakefulness.

Scientists have been able to show through the use of MRI (Magnetic Resonance Imaging) scans, some of the different processes the brain undergoes during the night, especially how information learned during the daytime has been processed. Essentially what happens is that during the period of wakefulness, let's say in the daytime, when information is absorbed from our surroundings and in lessons at school, it is held in particular areas of the brain. During the next period of sleep, in Stage 3 NREM, this information is transferred to a permanent storage location in our brains.

Studies have also shown that sleep-deprivation in humans and other animals affects how they perform in learning tasks, compared to other test subjects who had slept well.[37,38]

- **Polysomnography**

Polysomnography (PSG) is a sleep study test conducted to observe sleep in order to diagnose and determine treatment effectiveness for a variety of sleep disorders.

As far as sleep study procedures go, it's a non-invasive procedure that monitors sleep stages and cycles, brain wave activity, eye movements, limb movement, heart rates, respiration, body positions, sounds and blood-oxygen levels, through the attachment of wired sensors to the patient's body. The study results are produced in a chart called a *polysomnogram*.

By observing an individual's sleep cycles, along with the other empirical data the PSG study provides, it can help to identify disrupted sleep patterns.

Normally, a healthy person would go through several cycles of the NREM and REM sleep stages each time they sleep. Sleep disorders can disturb this normal sleep process so it's important for health, to identify the reasons behind disturbed sleep.

- **Sleep patterns**

Sleep patterns undergo significant changes throughout a person's lifetime. From the early years of childhood when a solid sleep pattern is established, possibly of up to 13 hours per night (that was me!), to the irregular sleep patterns of adolescents[39,40] being affected by many influences. Following on to the sleep patterns of young adults[41], then middle age where they settle down once more into habitual sleep patterns and eventually leading to the disrupted sleep patterns of the elderly who can awake several times each night with medical and other body-related issues.

For adolescents, these changes are characterised by a progressive delay in the onset of the sleep phase, known as '*Sleep Onset Latency*' accompanied by a decrease in the need for sleep.[42,43] This is usually due to internal factors like hormone balance and self-induced choices. Occurring at the same time and of no less importance, will be external factors, like regularly diarised schedules requiring early wake times. All adolescents probably wish that school started later but sadly this isn't feasible. This requirement to awake earlier during term-time weekdays often leads to shorter Total Sleep Time (TST) in adolescents.[44,45] The resulting sleep debt that accumulates during the school week will invariably lead to prolonged sleep duration over the week-ends. This cycle, whilst a pattern in itself, can lead to weekly sleeping pattern irregularities for adolescents.[46,47]

Several previous studies have highlighted corroborative evidence between use of electronic media and sleep patterns in both children[31,33,48-53] and adults.[51,54]

Previous studies have also shown that children exposed to electronic media, especially via a device in the bedroom, had a prevalence to later bed times and a shorter sleep duration.[32,33,48]

- **Sleep duration**

You must get a '*good nights' sleep*' is a common phrase that many adolescents will hear from the older generations but it is true and essential for long-term functioning of not just humans but all animals.

What we do know from studies into the field of sleep medicine is that without an adequate amount of sleep (duration), a person's ability to function will deteriorate.

Previous research studies[11,12] have shown that whilst sleep duration is a very important factor, sleep patterns are just as important, if not moreso, to the body's circadian rhythm.

Neurophysiologic and imaging studies conducted between 2005 and 2007, indicated that sleep affects the functioning of the brain's prefrontal cortex. This is the specific area of the brain that is responsible for higher brain functions like logic and reasoning, language interpretation & speech, creativity, alertness, attention, attentiveness and working memory.[6,7,55]

Studies of the children and adolescent demographics have also shown a correlation between late-night television watching and a significantly reduced total sleep duration.[56]

In adults, inadequate sleep duration is defined as fewer than 7 hours per day.[6,57]

- **<u>Sleep quality</u>**

Sadly, a reduction in sleep quality is now more frequent amongst adolescents. There has been a rise in the number of mental health issues, depression, Attention Deficit Hyperactivity Disorders (ADHD) and general anxiety disorders over the recent years within this age demographic.

In 2018, NHS Digital released data[58] showing mental health trends in children and young people since 2004. The results identified that 12.8% of children aged 5-19 years, have a mental health condition and that emotional disorders have increased by 48%.

According to a BBC News article[59] in February 2019, the number of adolescents reporting mental health issues to Child and Adolescent Mental Health Services (CAMHS) has more than doubled in England.

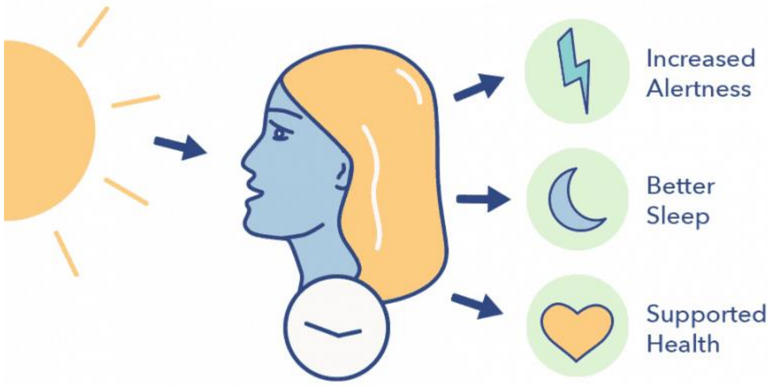
As a *Citizen Researcher* myself for the NHS CAMHS.Digital (*Children and Young People's Digital Research Advisory Group*), I can see at first-hand the increase in the number of adolescents suffering with anxiety disorders and the effects of this on sleep duration and quality.

This reduced sleep quality can lead to a compromised immune system as well as optimal cognitive and physical functioning and emotional development.[60]

CIRCADIAN RHYTHMS

All our bodies have an internal body clock. This is known as the circadian rhythm. It's the very reason why we fall asleep each night and awake in the mornings and why our bodies will generally feel tired or sleep around the same time each day, when averaged out over a long period. Our body clocks don't just exert control over our sleeping patterns, they also cause changes in our behaviour, control our levels of alertness, thermoregulation in the body and hormone production. Sleep is so hardwired into our biological processes that when it actually gets dark outside, we naturally will feel a lot more tired and the opposite when it gets lighter each morning.

Children and young people undergo additional changes. When adolescents reach puberty there are changes to their circadian rhythm that generally leads to delayed sleep onset. This has been identified in scientific studies.[61]



A Healthy Circadian Rhythm [62]

Around this time of reaching puberty, the body's biological clock undergoes these changes. If compared to a standard clock, we can say that it moves forward in time. It is for this reason that adolescents generally are unable to fall asleep as readily as other age groups or even as early as they themselves used to. When parents struggle to get their children or teens to fall asleep early, they're fighting against biology. The very same biological process their own bodies would have undergone, if they could only remember. This biological clock, the circadian rhythm, pushes their bodies to remain awake for hours longer. This is all part of a natural process.

The inherent problems with this is that when an adolescent's body clock influences them to remain awake for longer, this pushes them out of sync with the natural cycle of light and darkness, daylight and night time. Obviously, when you fall asleep later, that's partly what makes it harder to get out of bed in the mornings. This often leads to exasperation and unpleasant exchanges between parents and teenagers, with parents accusing them of being lazy and staying in bed for too long. This isn't the case at all.

Although everyone has a slightly different circadian rhythm, generally they're like a normal clock that follows a cycle of approximately 24 ¼ hours. Those people who are 'evening typed', tend to have circadian rhythms that are slightly longer and those who are early bird 'morning typed' are slightly shorter than the average.

The term '*circadian*' was named by biologists in the last century when they were trying to explain what was causing a daily cycle in the body. It comes from the Latin words '*circa*' meaning '*around*' and '*diem*' which means '*day*.' Around that time, biologists also had other words they applied to the durations of regular body cycles, for example, '*ultradian*' which was applied to body rhythms lasting under 24 hours and '*infradian*' for long-term rhythms lasting longer than 24 hours in duration.

Ultradian rhythms are things like your heart beating, respiration and your eyes blinking. These are things that you generally have little conscious control over and they're all vital functions in the body.

Examples of Infradian rhythms are things that last a lot longer and more prevalent in animals. The most notable of infradian rhythms in humans, affecting women, is the menstrual cycle.

This daily rhythm provides a link between wake and sleep times and thermoregulation in the body, the temperature control mechanisms. The human body finds it much easier to fall asleep when the body's temperature falls slightly. The reverse is true also, when the temperature rises, the body will tend to enter a wakeful state.

The circadian rhythm has been around for centuries and affected our ancestors just as much as it affects us today. It's a perfectly normal biological process.

Fortunately, society has also developed around these same cycles of light and darkness so they also affect not just our sleep patterns, cognitive, emotional and physiological functions but also social and economic events that occur each day. Hence, schools and businesses will, on the whole, only open during the hours of daylight.

This affect on our own biological functions throughout different times of the day leads us to be more able to perform certain functions optimally at different times of the day, from a cognitive and physical point of view. People perform better academically during certain times of the day and not during others. A person's mood can change according to where they sit on their circadian cycle during the day.

The processes that actually occur in the human body for the circadian rhythm to have these affects on sleep and wakefulness are better explained by comparing how much sleep a person has each week to the credits and debits on a bank account. Obviously a person's finances has little affect on their sleep, although I'm sure it can increase anxiety levels but I'm talking more about an accumulation or deficit of sleep in the body as a balancing equation.

Let's say that a person misses a lot of sleep over a few days, for example, a student busy studying for their exams or completing last minute assignments and they lose sleep in the process. If they would ordinarily sleep 8 hours per night but over the course of 3 days, instead they sleep only 4 hours each night, that's a sleep deficit of 12 hours over a week. Essentially this equates to 1½ days of lost sleep for this individual. What would normally happen in this case is that by the end of the week, when it gets to a Friday or Saturday night, the individual would sleep for a much longer duration, possibly even falling asleep far earlier in the evening than they would ordinarily do, even if it's still daylight outside. This is similar to what happens to people who work night shifts. Towards the end of their pattern of night shift, they start to fall asleep at irregular times and are even prone to micro-sleeps when stationary at traffic lights whilst driving home from work.

It's not just daylight that affects how sleepy a person can feel. It can also be things like a regular social life, events and activities with family members and friends. All of these can cause disturbances to sleep patterns and the circadian rhythm and result in some serious health concerns, affecting mental health, appetite and leading to episodic depression. This leads to what's known as *circadian rhythm sleep disorders* (CRSD). Studies have estimated that approximately 16% of adolescents may have a CRSD.[63-66]

People who suffer CRSD’s can experience a reduction in their quality of life with things like intolerable mood swings, impaired cognitive functioning and lower levels of attentiveness. Long-term sustained CRSD’s can even lead to mental health issues and physical disorders.

A recent phrase that has been applied to a temporary disturbance of circadian rhythms as a result of social activities is, ‘*social jet lag*.’

One of the regular and scheduled activities that are unavoidable for students is their weekday attendance at school. This is a fixed time and can’t change. The problem occurs when adolescents have gradually later sleep times and in order to maintain regular sleep duration, the wake-up time should also be later in the morning but it’s not. It can’t be because school is at a fixed time each day. This also leads to a reduced sleep time each weekday and the need to catch up on this sleep deficit during the weekends. Hence, adolescents will invariably sleep in for longer during the weekends. This is not laziness, this is a biological imperative! It’s our bodies catching up on sleep deficit.

The science of circadian rhythms has been around since the 1950’s but it has only been very recently that a spotlight was shone on this particular area of science. In 2017, the Nobel Prize for physiology or medicine was awarded to 3 scientists from the USA, Jeffrey Hall, Michael Young and Michael Rosbash. Their studies were in the field of circadian rhythms, undertaking a study using fruit flies to explain how molecular feedback loops maintain time in all animals.

In their studies, Hall and Rosbash identified a section of DNA which had an affect on circadian rhythms. They called this the ‘*period gene*.’ This gene was the building blocks for the synthesis of a protein called PER. What happens is that when levels of this PER protein increase, there is a feedback loop that reduces the synthesis of PER. This causes a 24 hour oscillation in the production of the PER protein, which builds up overnight and breaks down during the daytime.

Nobel Prize Winners – Jeffrey C. Hall, Michael Rosbash & Michael W. Young [67]

Young furthered the studies by identifying 2 other genes which he termed, '*timeless*' and '*double-time*.' Both of these genes affect the daily oscillations of the PER protein.

There's other mechanisms working in the body to regulate the circadian rhythm. These are called *heterodimers* and the specific ones that affect circadian timings are BMAL1, CLOCK, and NPAS2. It is these that create the proteins PER and CRY and interact in a constant daily loop to either promote or suppress protein production.

It's not just humans that have circadian rhythms, these internal clock cycles occur in nearly all animals as well as plants and basic organisms like unicellular bacteria.

As an interesting side note, there are some mammals and plant life that thrive in tidal areas and have circadian rhythms that sync with both the lunar cycle and tidal patterns.

Our fascination with the body's rhythms being synchronised with daylight and darkness have been around for centuries.

If we look to religious scripture, in The Bible, it shows that God created a daily rhythm of light & darkness. In Genesis 1, v1-5, it states,

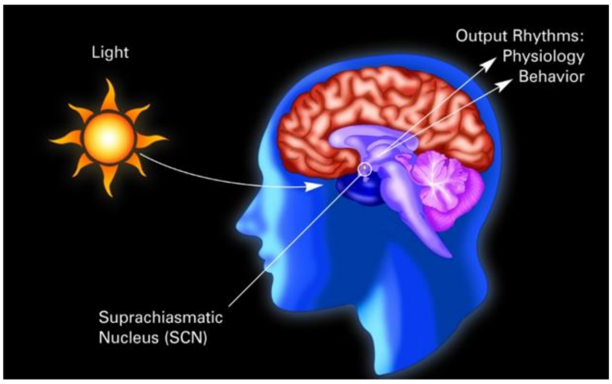
"*In the beginning God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters. And God said, Let there be light: and there was light. And God saw the light, that it was good: and God divided the light from the darkness. And God called the light Day, and the darkness he called Night. And the evening and the morning were the first day.*"

Rolling the clock forward in time, in 1729, the French astronomer Jean-Jacques d'Ortous de Mairan demonstrated that certain plants called mimosa, opened their leaves automatically during the daylight and closed them at night-time. He tested his hypothesis by conducting his experiment also in full darkness. The results were exactly the same. This indicated that the mimosa plants were somehow reacting to the diurnal changes between daytime and night time and not light and darkness and that whatever mechanism was controlling this process was inherent and internal.

Jean-Jacques d'Ortous de Mairan

It has even been discovered that neurons in a petri dish in a lab have their own circadian rhythms and act like clocks.

Whilst there can be regular disturbances to the circadian rhythm, it can be reset on a regular basis. The simplest way to do this is by using *chronotherapy* and introducing bursts of daylight into our eyes. Our eyes are especially sensitive to the shorter wavelength blue light. The best way to re-synchronise our circadian rhythms is to expose our eyes to sunlight. This can be done with a simple walk in the outdoors. It has the added effect of increasing vitamin D in the body which also has the benefit of reducing the likelihood of depression.



Suprachiasmatic nucleus (SCN) [68]

Throughout this entire biological process that we're referring to as the circadian rhythm, the brain is in control of this function. In 1972, it was discovered that there is a network of smaller oscillators in the brain that function as the master controller in this process. It's called the *suprachiasmatic nucleus* (SCN) of the hypothalamus.[69,70]

SCN's can exist outside the human body and they have been observed in a laboratory under scientific conditions, moving individually in their own circadian rhythms. However, in our brains the SCN's all oscillate together, in rhythm.

So how does this synchronisation occur? What happens is that daylight reaches our eyes and the neurons in the retina called '*ganglion cells*' then transmit a signal to the SCN's. There is a process occurring within the ganglion cells that involves both of the pigments *melanopsin* and *cryptochrome*. However, at this stage, still not enough information is known to deduce to what extent their role plays in this process. What we do know is that the rods and cones in the retina aren't directly involved.

It's interesting that blind people can sometimes suffer with circadian rhythm sleeping disorders because light doesn't get detected by their retinas and therefore unable to send signals to the SCN's.

Once your circadian rhythm is in sync with the light/dark phase in the natural environment, you'll experience reduced alertness and feel sleepy and your body temperature will be lower during the night whilst your melatonin production levels peak. In the morning, you'll feel more alert and have a higher performance capacity for exercise or academic performance.[71,72]

Circadian rhythms are affected by and have their effects on so many different aspects of our bodies and health. We will review some of those more closely here.

- **<u>Genetic chronotypes</u>**

  Chronotype describes whether a person is a morning person or a night owl.

  It's very possible that our own chronotypes are influenced genetically and passed down from our ancestors.

  We know that our own circadian rhythms occur on a cellular level, having observed that cells in a petri dish in a science lab exhibit their own timing.

- **<u>Changes with age</u>**

  It was previously considered that adolescents have a longer circadian rhythm to adults and this was thought to explain why teenagers sleep-in for longer but as we now know, that's primarily due to an accumulation of sleep debt which occurs over the week.

This is, however, a change that occurs with age but rather than it being on a cellular level, it's more on a neurological level.

As we age, melatonin production decreases and this presents itself symptomatically with broken sleep throughout the night and a decrease in delta wave slow-wave sleep (phase 3 NREM sleep).

Another aspect that occurs, sadly, with age is that of macular degeneration. When the retina is unable to process the same amount of light, it can't send the necessary cues for an optimal circadian rhythm.

We looked earlier at social factors that might contribute externally to providing stimuli for affecting circadian rhythms. These are things like alarm clocks beeping early in the morning, scheduled school times or work times. For the elderly, these external cues might not be present. When they leave their jobs and retire, there's a reduction in these sort of stimuli and so the regularity of their everyday lives is lost.

- **Seasonal shifts**

Seasons have always had an affect on our bodies and how much we sleep.

In some animals, seasonal changes trigger hibernation.

There is a dramatic difference in the hours of daylight during the seasons of summer and winter. As we know, light is one of the significant external factors that changes our circadian rhythms.

During the summertime, when there's more daylight, we tend to sleep longer, better and feel more alert during the daytimes. The opposite is true in the winter months, when there's far fewer daylight hours. During the winter, we will often sleep less, experience more sleeping disorders and feel more sluggish during the daytime.

Seasonal changes in circadian rhythms

The body produces less melatonin and serotonin during the darker hours of these winter months.

You can see this effect more clearly in the higher latitudes of the northern hemisphere, with people living in the Nordic countries, who experience even less daylight in the winter months than those at the equator. For them, the problems will be more pronounced. Perhaps this is even one reason why depression and suicide rates are higher in the Nordic countries, as a result of reduced melatonin and serotonin production.

- **Exposure to light**

Adolescents aren't lucky enough to have much exposure to the morning daylight, often being stuck indoors, in a classroom learning or on transport heading towards school.

This is an important reason for adolescents to make good use of the morning break at school and to either peer through a window or even head outdoors to experience the shorter wavelength blue light from the morning daylight.

This blue light, however, can have the opposite and more harmful affect in the evenings, supressing melatonin production and delaying sleep onset. It is for this reason that the use of bedtime technology with light-emitting screens should be limited during the bedtime hours.

- **Hours of screen time per day**

Your hours of screen time per day will be directly proportional to the amount of blue light emissions your retina receives. This doesn't present any issues during the daylight hours when we would ordinarily receive light from the sun. In fact, in some cases it can even be beneficial, especially for people who are confined indoors and don't get sufficient sunlight.

However, in the evening and at night, exposure to light-emitting screens can affect our circadian rhythms.

The overall amount of time spent in front of screens per day isn't the issue and I feel this is where the current World Health Organisation guidelines are wrong. What is more relevant is the exposure to screens later in the evening when the body should be producing melatonin.

- **Daytime Inattention**

With an unhealthy circadian rhythm that is out of sync with the natural hours of daylight and darkness, this could lead to disturbed sleep. Along with disturbed sleep comes sluggishness upon wakening and reduced performance and attention during the daytime.

- **Academic performance**

We can probably all accept by now that with reduced sleep, you're likely to suffer reduced cognitive performance and motor neurone abilities. This means that over time, with consistent or reduced sleep, an adolescent's academic performance will degrade.

A study conducted by Yoo et al[8] highlighted that just one night of reduced sleep resulted in decreased memory functions and reduced memory retention.

In several other research studies, there was shown to be a direct causal link between reduced academic performance in adolescents and reduced sleep with resultant fatigue and daytime inattentiveness.[73-75]

Research studies have previously concluded that academic performance is at its optimum of cognitive functioning when the subject has undergone a period of sufficient quality sleep.[76]

That concerns the affect of sleep on academic performance but what about the affects of circadian rhythm? This is sometimes referred to as the '*synchrony effect.*'[77]

This synchrony effect describes what happens when your circadian rhythm is at its peak and you're feeling very alert. During this state, your academic performance will most likely also be at its peak. The reverse is also true. When you're circadian rhythm is in a trough and you're feeling sluggish, it's most likely that your academic performance will be negatively affected.

Other research studies looking into epidemiological and experimental sleep restriction methods, have identified that insufficient sleep or delayed sleep onset has an affect on academic performance and health, possibly as a result of inattentiveness or somnolence.[78-81]

In a 2007 article in the New Yorker Magazine,[82,83] it provided a compilation of relevant sleep study findings up to that date. It demonstrated that all the studies came to the same conclusion, that there is a direct correlation between the number of hours a child sleeps per night and their academic performance.

- **Known health issues**

A sustained pattern of poor circadian rhythm can not only lead to such things as CRSD's and daytime inattentiveness but also other health concerns which may not become apparent for a while. Unless there is a significant and improved sleep pattern, the daily neurotoxins that build up in the brain will make you feel sluggish and possibly even with impaired judgement. This also has the effect of reducing the body's metabolic rate.

The effects can lead to things like long-term depressive episodes, paranoia, decreased physical health, diabetes, obesity, anxiety disorders and other mental health issues.

At the more serious end of the scale, as a result of these symptoms, they have been known to lead to more life-threatening diseases like cardiovascular disease and breast cancer if the effects are pronounced and over a period of several years.

- **Hormones & Pigments:**

  - **Adrenocorticotropic Hormone (ACTH) & Corticotropin Releasing Hormone (CRH)**

    Adrenocorticotropic Hormone (ACTH) plays a very important role within the circadian rhythm. Levels of ACTH in the blood are inversely proportionate to melatonin levels, with higher levels during daylight and lower levels during the hours of darkness.

    When an adolescent's circadian rhythm is affected, for example, through social jet leg or even jet lag itself or other periods of extended affected sleep, this affects the levels of both melatonin synthesis and ACTH in the body.

    We've already seen that the hypothalamus, located in the middle near the base of the brain, plays an important role in the regulation of many important features in the body, it also releases another hormone integral to circadian rhythms, called Corticotrophin Releasing Hormone (CRH). A release of CRH stimulates the synthesis of ACTH from the pituitary gland, which then triggers a response in the adrenal cortex. This is a very essential mechanism in the regular functioning of the body.

What happens is that once the ACTH has stimulated the adrenal cortex, this triggers the production of several other important biological functions like testosterone, progesterone, oestrogen and the stress hormone cortisol. It also stimulates the synthesis of aldosterone which plays an important role in regulating blood pressure by acting upon kidney functions and the colon.

As well as the regulation of blood pressure being a side-effect of ACTH production, being cholesterol based, ACTH also has the added effect of lowering lipid levels in our blood.

- **Neuropeptides & Growth Hormone**

Neuropeptides are small protein-like molecules used by neurons to aid the flow of communication between one another.

A 1997 clinical research study[84] indicated that neuropeptide Y (NPY) affected the rate of secretion of growth hormone (GH) in several different species of animals.

The reciprocal interaction of the neuropeptides and growth hormone-releasing and the Corticotropin Releasing Hormone (CRH) play a key role in the regulation of sleep.[85]

- ## <u>**Melatonin**</u>

Melatonin is a hormone that plays a very important role in the body's circadian rhythm cycle.

It is produced in the pineal gland in the brain and synthesised in response to stimulus from light and darkness. This is what regulates the production of melatonin.

Low levels of melatonin can lead to disrupted sleep, insomnia, daytime inattentiveness, irritability and mental health issues.

A 2018 study[86] showed that production of the hormone melatonin helps to inhibit the production of other particles known as '*reactive oxygen species*' which are known to cause damage to our cells. Sadly, these reactive oxygen species are associated with several pathological conditions, including cancers.

Melatonin is also helpful in regulating core body temperature at night and cooling the body.

Due to the effects of short-wavelength blue light, it is now known that using blue light-emitting screens late into the night has the affect of suppressing melatonin production in the body. It's even been shown that using technology with much lower levels of ambient light, for example, dim bedside lamps and plugin-in nightlights, can reduce melatonin production.

In 2016, associate professor at Rensselaer and director of the LRC's Light and Health Program, Mariana Figueiro reported that,

'*Our study shows that a two-hour exposure to light from self-luminous electronic displays can suppress melatonin by about 22 percent*.'[87]

When using light-emitting screens late at night, for example, mobile phones, tablets or television, turn the screen brightness control down or use a blue light filter where possible.

- **Cortisol**

Cortisol is known as the 'stress hormone.' It's produced in the adrenal gland and partly responsible for waking us up each morning.

In that regard, it's almost the opposite of melatonin which, being produced increasingly throughout the afternoon and evening, helps us get to sleep. Whereas cortisol is the opposite and is produced to have entirely the opposite effect.

When cortisol levels rise, this also has the effect of supressing the production of ACTH and CRH. For those suffering with stress, this can frustrate the normal daily circadian rhythmic regulation of these hormones and lead to the adrenal gland producing excessive amounts of these hormones. This can in turn lead to sleep disorders and other physiological conditions and eventually to what's known as '*adrenal burnout.*'

- **Adrenaline**

Adrenaline, also known as epinephrine, is a hormone produced in both the adrenal gland and a small number of neurons in the medulla oblongata in the brainstem.

Adrenaline is key to certain bodily functions. The fact that adrenaline is given as medication at times, shows just how important it is to our biological functioning.

Adrenaline increases blood pressure and heart rate, enlarges the eye pupils and quickly moves blood to the muscles. These are all very similar responses to that which your body undergoes when in shock.

Adrenaline is also released during what we call the '*fight-or-flight response*.'

Our bodies will tend to go into this fight-or-flight response when we're under heightened periods of stress, dangerous situations or at times when you feel threatened. The adrenaline is released to make your body respond a lot quicker to the situation. This is when an adrenaline rush occurs.

There's many symptoms of over-production of adrenaline and these include a rapidly increased heart rate, increased blood pressure, palpitations, anxiety and in the long-term, weight loss.

A century ago, the stressors to produce adrenaline rushes were a lot more physical in nature, from things like escaping a marauding army of Romans, invading Vikings or some wilder beast. In this modern age, the stressors are mostly mental or emotional stressors but these nevertheless invoke the same sudden rush of adrenaline. Imagine lying in bed each night and worried about your financial situation or an upcoming exam. These thoughts and anxieties will race around your head and eventually manifest themselves with the physical symptoms of an adrenaline rush.

The problem occurs because whilst you perceive danger and a threat from whatever is causing you anxiety, the danger itself is not present at that moment and so you can be left feeling like your body is slightly shaking, irritable and restless.

If this occurs very close to bedtime, perhaps through over stimulation of the mind from violent or aggressive video content on YouTube or TV or even reading an unpleasant message on social media, it can leave you with disrupted sleep and a broken circadian rhythm.

- **<u>Melanopsin</u>**

In humans, photoreception can only take place in the retina.[88]

Melanopsin is a photopigment protein, found primarily in the intrinsically photosensitive retinal ganglion cells (ipRGCs) of the retina at the back of our eyes. Unlike the rods and cones in our eyes, these cells don't relay images to our brains. Instead, the melanopsin in these cells helps them to process levels of ambient light and relay this as signals to aid the circadian rhythm in the body.

After just 10 minutes of exposure to a light source, this causes the continual synthesis of melanopsin. In turn, the brain translates these signals into responses that control our levels of alertness and wakefulness. This also causes the suppression of melatonin.

A series of studies conducted throughout the 1990's identified that mice in a laboratory that lacked photoreceptor rods, had a normal response to ambient lighting.[89] This is known as a normal phase response curve (PRC), with responses that peaked around 480 nm light emissions.[90]

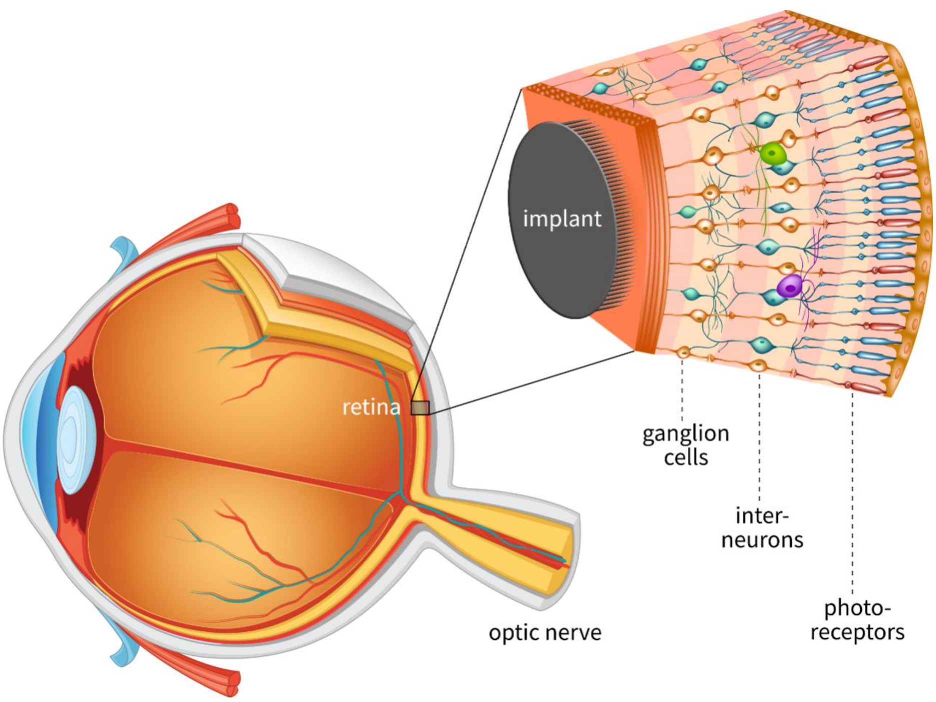


Diagram of an eye, showing retina, ganglion cells & photo-receptors [91]

These studies indicated that the circadian rhythms in the lab mice were being affected by photo pigments other than rhodopsin and opsin.[92] Further studies were conducted which showed that mice without either rod or cone photoreceptors were still able to synchronise their circadian rhythms to the natural daily cycle of light and darkness.[93]

In a 2018 study by the Salk Institute, staff scientist Ludovic Mure conducted research in this area and produced a research paper on the, '*Sustained Melanopsin Photoresponse Is Supported by Specific Roles of b-Arrestin 1 and 2 in Deactivation and Regeneration of Photopigment.*'[94,95]

In his research he stated,

"*Compared to other light-sensing cells in the eye, melanopsin cells respond as long as the light lasts, or even a few seconds longer. That's critical, because our circadian clocks are designed to respond only to prolonged illumination.*"

As part of this study, the research team was able to isolate the melanopsin retinal ipRGCs cells and stimulate its production.

The results showed that during this period of exposure to light, a protein called arrestin works to keep the melanopsin sensitive to the incoming light. Those melanopsin producing cells that didn't contain either beta-arrestin 1 or beta-arrestin 2 were shown to lose their sensitivity to sustained exposure to light.

What this research study did was to indicate that the melanopsin retinal ipRGCs cells needed both different types of arrestins in order to maintain sensitivity and continue to synthesise melanopsin.

Other research studies have proved that melanopsin-based photoreception affects the promotion of sleep.[96-99] A 2012 study[100] also showed that mood and learning are both affected through melanopsin-expressing neurons.

- <u>**Dopamine**</u>

Interestingly, circadian rhythms also involve a chemical that's both a hormone and a neurotransmitter, called dopamine.

In popular culture, dopamine is seen as the main chemical of pleasure, cravings and desire and often associated in the media with consumption of chocolate.

Researchers believe that dopamine is released in adolescents when they satiate their desire to remain engaged with news feeds on social media.

In 2018, CBS News covered a study[101] conducted by the American National Institute for Health (NIH). Dr. Kara Bagot who was part of this study, used MRI to scan the brains of teenagers as they checked their Instagram feeds to see whether the reward systems of the brain are activated. The resulting data showed that screen time is likely to stimulate the production of dopamine. It is for this reason that many new studies are now also looking at the affects of other social media channels, like Facebook, Snapchat and even YouTube.

This may go some way to explaining why we feel almost addicted to using our electronic devices, not through necessity but more to satiate a craving.

- **Other things that can affect circadian rhythms:**

  - **Personality type**

    People with a type ‘A’ personality trait, in other words, those who are overworked, stressed, sensitive and anxious, will be more likely to have affected circadian rhythms through the over-production of adrenaline.

  - **Emotional health**

    Your emotional health will dictate, to some degree, how easily you can get to sleep each day, what worries you have in life, whether you’re feeling depressed, how sensitive you are, etc.

    All these things and many more are all part of our emotional health and can affect our biochemistry, which in turn, can lead to the production or suppression of various hormones that will affect the circadian rhythm.

- **<u>Presence of stressors</u>**

  The last thing you want late at night, before going to bed, is something that causes undue stress and anxiety.

Imagine scrolling through Facebook and seeing something horrendous on the news feed, something that makes you feel very angry or depressed, perhaps an unpleasant photo or a nasty comment. Along with the release of cortisol and adrenaline you will experience a suppression of melatonin. Even if you see something that makes you laugh or happy or changes your emotional state, it will most likely lead to delayed sleep onset.

The problem is because certain things like mobile phones have become such a zeitgeist and part of our everyday lives, you can't just take those stressors out of the equation. Even if you don't pick up your phone and look at it, you will still feel the anxiety of not knowing what's happening in social media. It's the recently termed '*Fear Of Missing Out*' (FOMO).

Just hearing the notifications pinging away at night on your phone or tablet can increase anxiety.

We have all turned into *Pavlov's Dog*, named after the Nobel Prize winning Russian physiologist Ivan Pavlov's theory. We usually read phone notifications immediately and so pre-condition ourselves to want to read them straight away during the night. So much so that many of us will lie there waiting for the notifications to come in, just like Pavlov's dog hearing the dinner bell ringing.

- **Time management**

If you're better able to manage your time, you'll be less stressed at the end of each day. If you can also plan out your time for each day in advance, you'll have less uncertainty in your life and this again leads to reduced or at least manageable levels of stress.

This leaves the mind less anxious at the end of each day and not as prone to cortisol or adrenaline rushes.

- **Diet**

It's important to align our eating patterns with our circadian rhythms and eat at regular intervals at similar times each day.

Not only are consistent meal times important but also what we eat is equally as important. You are what you eat and this maxim holds true as our diet partly determines our own biochemistry and the resultant circadian rhythm.

- **Exercise**

Research has shown that those who engage in exercise, are more likely to live a healthier lifestyle and have a better balance of the right biochemistry all doing the right things at the right time with their circadian rhythm.

It has the added effect that doing physical exercise does in itself create a natural fatigue in the evenings, which makes periods of quality sleep more prevalent.

- **Caffeine use**

Caffeine is a stimulant and an appetite-suppressant. The likes of coffee and tea are drank, often, with the intention of increasing wakefulness.

In a 2015 study, caffeine consumption was shown to delay the production of melatonin and have a pronounced affect on circadian rhythm.[102]

BEDTIME TECHNOLOGY

Sadly, as a condition of society and technology in use in the world today, many people, especially adolescents incorporate technology and media use into their personal bedtime routine. This has been driven by a need to remain constantly connected with friends but also as screens have become more compact, it's made them a lot more portable and easier to have in bed and closer to the face.

In a 2019 engagement exercise conducted by the RCPCH (Royal College of Paediatrics & Child Health) involving 108 children and young people aged 11-24 years, 88% of their survey respondents said that they believed that media screen time had a negative affect on their sleep. They also reported that 1½ hours was the average time respondents spent looking at screens before they fell asleep.[103]

Another theme that is becoming apparent, especially with adolescents is screen multi-tasking or '*screen stacking*' as it's also now called, where adolescents will tend to watch

content on multiple screens at the same time. This is an extension of adults watching TV whilst simultaneously working on their laptops. In the same way, school students will perhaps now watch something from YouTube on their phones, whilst simultaneously on a laptop or games console, perhaps even with the TV on in the background. One screen will be enabling social contact with their friends.

There has in recent times been a change, however, from the initial belief that the amount of screen time an adolescent accumulates during a day will affect the amount of sleep they have. In 2018, the BBC News[104] reported on a study undertaken by the Oxford Internet Institute, University of Oxford, which relied upon data obtained from a 2016 US study published in the *Journal of Pediatrics*,[105] concluding that the overall time spent on a screen by a child during the daytime had little effect on the duration of sleep per night. That study concluded that every hour of screen time was linked to a sleep loss between 3 to 8 minutes of sleep. Prof Przbylski from the Oxford Internet Institute told the BBC that this particular study along with other studies into screen time, only analysed the affect of overall screen time and not which specific bedtime technology was used. The studies have also only assessed affect on sleep and not circadian rhythms.

It used to be that children would go to bed watching television but since laptops became more compact, a few would also take laptops to bed. Following on from the introduction to consumers in 2007 of the iPhone and quickly followed by many android phones, many of the previously used gadgets were all combined into this one unit. As a result of this and its small size and portability, the whole bedtime technology architecture changed and many adolescents and adults too, now take phones to bed with them.

The problem is that because the internet is accessible on mobile devices, it essentially means that the whole world of information is available at your fingertips. Human beings, being as inquisitive as we are, just can’t resist jumping into this never ending pit of information and absorbing it very late into the night. It also brings us, socially, closer together.

Prof Jan Van den Bulck[32,106] in both his 2004 and 2010 studies, highlighted the haphazard approach that we all have towards using electronic media. He highlighted the contrast with other leisure activities by rightly pointing out that using electronic media is an unstructured activity that doesn't have any clear endpoint.

- **<u>Types of devices</u>**

There are so many different types of devices that can be used late into the night. They all share things in common, such as the improvements in technology making most devices smaller, more portable and more accessible. In all instances, they all have their own ability to make the user form an addiction to using them and continue using them long after the lights should've been turned out for bedtime.

  - **<u>Television</u>**

Since one of the co-inventors, the Scottish man John Logie Baird, gave the world's first demonstration of true television before 50 scientists in an attic room in central London on 26th January 1926, it has found its way into the home of the majority of people on the planet.

By 2013, 79% of the world's households owned a television set.[107]

Television has come a long way since its introduction and it's also changed from the old cathode ray tube (CRT) design to the modern-day liquid crystal display (LCD) type. They also no longer show only television programmes but with the advent of SMART TV, you can access the internet and many more services through this same box.

The largest problem with watching television at bedtime is not so much from the blue light emission but more from the affects of watching the programme content on the human mind. Imagine, instead of settling down to quietly reading a book in bed, you instead switch on the television and watch a scary film or an action film with lots of violence and suspense. This would leave you feeling anxious and possibly with your body undergoing the fight or flight response. Another effect could be that watching something so suspenseful may leave you wanting for more and this ends up with binge-watching entire TV serieses just to see what happens next.

- **Computers**

Computers are very similar to televisions in the content that the end user can view on them. They can now access not only the internet and television channels live and streaming but they can also be using for gaming. They really are a cross-functional platform.

Gone are the days when a house would be lucky to have just one computer set aside for the use of the whole family, nowadays, the norm is for each member of the family to have their own computer.

Technology has improved so much that the large, clunky computers have now been replaced with very thin and light laptops. These make it so easy to sit in bed, late into the night, remaining active with the computer.

That said, the same issues occur as with a television set and these are from the blue light emissions from the screen and also the affects of viewing whatever content is being displayed.

- **<u>Entertainment consoles</u>**

Entertainment consoles grew from the 1970’s where they had Atari and other large consoles which require the user to plug in cartridges and large arcade machines. These required the user to watch the game over the television set by plugging the console into the TV.

Computer gaming became more popular throughout the 1980’s and 90’s when people could play them on their household computers.

Moving forward quickly to today, we now have the top entertainment consoles in the world, the Xbox1 and the PlayStation. Once again, these require the console to be plugged into the TV set.

This emits both blue light into the room but also, has the same effect as watching a suspenseful TV programme because games are no fun if they’re not making you constantly sit at the edge of your seat whilst playing. So playing entertainment consoles close to bed will undoubtedly release cortisol and adrenaline and act against the body's circadian rhythm.

Gaming is also more popular when played in multi-player mode so this increases socialising and interactions closer to bedtime.

As well as the full-size entertainment consoles, there are also the smaller Nintendo devices that fit in the hand. This degree of compactness and portability lends itself well to use in bed and as another distraction from sleep.

- **Mobile phones**

Mobile phones have been around since the late 1980's but only really became popular, as they became more portable, in the mid 1990's.

Since the introduction of mobile phones into modern society, they have become a zeitgeist, growing in popularity as communities strive to increase communication between each other and finding their way into everyday life.[108] This desire for increased communication through various modalities, came with the introduction in 2007 of the Apple iPhone.

This wasn't so much a mobile phone but more of a pocket computer. Being so multi-functional,[109] it effectively combines every item of bedroom technology into one, small, portable unit, making them increasingly popular.[110,111]

By 2013, mobile phones had become so commonplace that their use had soared to over 90%, with more than half of the phones in circulation being of the multi-functional smartphone variety.[112] The very nature of the multi-faceted use of smartphones has made them so popular amongst children and young people[113] as one of the most commonplace methods to communicate.[15]

The problem with making people so accessible is that we, as humans, have a need to be constantly connected with society. No-one wants to be alone. This has led to a rise in many people taking their phones to bed with them. Some people will even stay awake late into the night just to respond to any notifications as and when they are received.[114] Another feature of this is that some people can have increased anxiety just waiting for messages to arrive.

Much of the content received on mobile phones well into the night, whether it's as part of a group social chat or viewing something over social media, watching a TV programme or playing a game, will be of a stimulating nature and again this will affect the biochemistry of the end user, possibly causing them to remain awake later.

Another feature of mobile phones in the bedroom is that because they are so small, many people have them not just by the bedside but actually in the bed with them.

- **Parental influence**

Psychologists will argue between genetics and learnt behaviour but in my opinion, a lot of things that adolescents will do around the home is from learnt behaviour, either from their peer group or their close family.

Children will always learn their sleeping pattern from their parents in their formative years. They're always watching and learning. If parents don't sleep well, it could be genetic but children will learn to also stay up late. This sleep behaviour is influenced in the same way that diets are often common throughout the same household.

Likewise, if a parent doesn't exercise enough discipline or educate around bedtime behaviour then it's very possible that some adolescents will be awake well into the night and early hours of the morning, using bedtime technology.

In 2010, Shochat and colleagues[33] studied sleep-related behaviour amongst a group of adolescents in Israel. Their study results suggest that having some sort of electronic media device in the bedroom may indicate high availability of the device in the household and low parental control.

Interestingly, some of the world's leading technology experts have placed bans of sorts on their own children's technology use.[104] The founder of Microsoft Bill Gates banned his children from having phones until they were teenagers. Steve Jobs from Apple wouldn't allow iPads and even the current CEO of Apple, Tim Cook doesn't want his nephew to join any social networks.

AFFECTS

The use of bedtime technology can have multiple affects and all can operate on a person simultaneously. Each of these affects can interact with each other and cause additional problems with both mental and physical health.

In a 2008 study by Soderqvist et al.[115] who conducted research into Swedish adolescents aged 15–19 years, using a self-reported instrument, they found that of the adolescents who regularly used mobile phones, they experienced affects on their health. Such health concerns were things like lethargy, inattentiveness, reduced concentration, sleep issues, stress and anxiety.

In a 2010 study, researchers Cain and Gradisar[53] identified several factors that have the potential to decide to what extent the use of bedtime technology can affect circadian rhythms. These are both genetic and learnt traits with things like a person's socioeconomic status and their background, parental influence and the duration and intensity of the use of electronic media.

Let's review these individual affects that bedtime technology can have on our health.

- **Sleep disturbance**

  Whilst there has been much research conducted since a previous research summation of 36 independent studies conducted in 2010,[116] it was identified then that electronic use in children and adolescents was causing sleep disturbances.

In another research study conducted by Munezawa et al,[117] they processed and analysed data from 94,777 questionnaire responses completed by both junior and senior high school students studying in Japan. After analysing the data, this research study, which focused only on mobile phones as a form of bedtime technology, showed that using mobile phones for both phone calls and texts after going to bed, was associated with disturbed sleep. The study results were born from a self-reported questionnaire and highlighted such disturbances as reduced sleep duration, daytime somnolence and insomnia.

The connection between use of electronic media and poor sleep quality has been identified through several different research studies.[118,119,120]

In 2014, Fossum et al.[118] progressed the previous research conducted in Japan by opening the goal posts further and investigating whether electronic media in general and not just mobile phones, caused sleep disturbance. Their study focused on students aged between 18 and 39 years of age. Their study identified that there was a positive correlation between smart phone use and insomnia and a negative association with morningness.

- **Sleep displacement**

Studies have shown that sleep displacement is the strongest amongst the children and adolescents age demographic.[121-123]

The problem is that, unlike many other modern day activities like playing football, sports games, dance class and music lessons, the use of bedtime technology is very much an unstructured activity. That is to say, there's no designated start and end times.[124] As a result of this absence of time boundaries, it is more likely to lead to time displacement.[125,126] This is even more the case when the use of electronic media occurs during bedtime when there are no other time distractions or impediments to use.[127,128]

This time displacement can often result in sleep displacement with common bedtime media use.[129,130] As we have seen already, this displaced sleep causes sleep deficit and a good reason why adolescents tend to sleep in for a lot longer over the weekends.

Sleep latency may be compounded by the use of mobile phones, extending waking hours further into the night to enable the furthering use of the mobile phone.

In a study conducted by King et al. in 2013,[131] they surveyed the effects of adolescents playing violent and aggressive video games just before bedtime. Their results showed that sleep efficiency and total sleep time were reduced, along with an increase in Sleep Onset Latency (SOL).

This impaired sleep has knock-on effects with the body's metabolism, increasing the likelihood of dietary issues and an increase in caffeine consumption as a stimulant amongst adolescents.[132,133] Concomitant to this increase in caffeine consumption[134] and impaired sleep is the emergence of daytime somnolence and reduced performance.[135]

- **Time Shifting**

Other studies have shown a phenomenon known as '*time shifting*.'[136,137] This is the process where use of bedtime technology displaces sleep to a later bedtime and as a result, a later awake time occurs the following morning. This means that whilst there is a positive time shift in sleep, there is no overall reduction in the duration of sleep. However, this presupposes there is a requirement for the adolescents to wake up at a set time, e.g.- for school, etc.

- **Psychophysiological (Physiological, Emotional & Mental) arousal**

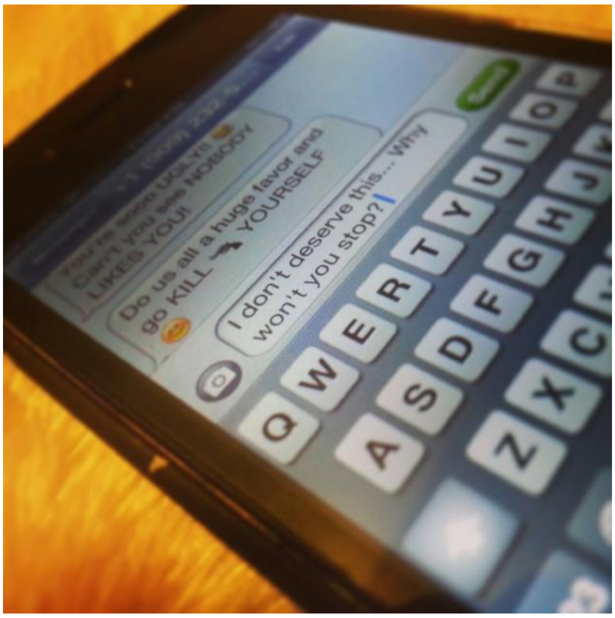
A psychophysiological arousal is something that stimulates our physiological, emotional or mental states.

Research studies[138] looking into the affect of entertainment consoles and mobile phones on adolescents has shown that using these forms of electronic media before bedtime, increased psychophysiological arousal.

Studies have indicated that the very nature of the content viewed over electronic media and mobile phones, is a strong reason for affected sleep.[120] Sometimes this content can be excessively violent in nature[139,140] and prone to stimulate stress reaction in children and adolescents and the fight-or-flight response.[141-143] Sleep disruption can also occur due a combination of all these factors like content arousal, light emissions from the media screens and the technology use replacing sleep time.[144]

Mark Rosekind, PhD, is a former director of the Fatigue Countermeasures Program at the NASA Ames Research Center. He stated,[145]

"*One of the most simple but important reasons technology affects our sleep is cognitive stimulation*."



He highlighted the effects of this stimulated arousal and pointed out that when electronic media is used, electrical activity in the brain activity is stimulated and neurons start to fire, pointing out this is the opposite of what should actually be happening to induce a restful state or sleep.

Rosekind also discussed how it's not only psychological arousal but also there's some degree of physical arousal if the body experiences a fight-or-flight response with muscles contracting and the body becoming more tense. Even an irritating text or upsetting email content can create this response which triggers the release of adrenaline and cortisol, supressing melatonin production and making sleep so much harder.

A lot of adolescents will now feel some degree of anxiety if they don't check their social media news feeds regularly and continually engage with their friends and social groups.

This is no different to how people will often have nightmares during their sleep if they have watched a violent and scary horror film just before bedtime. This is a stress response and a form of sleep disorder.

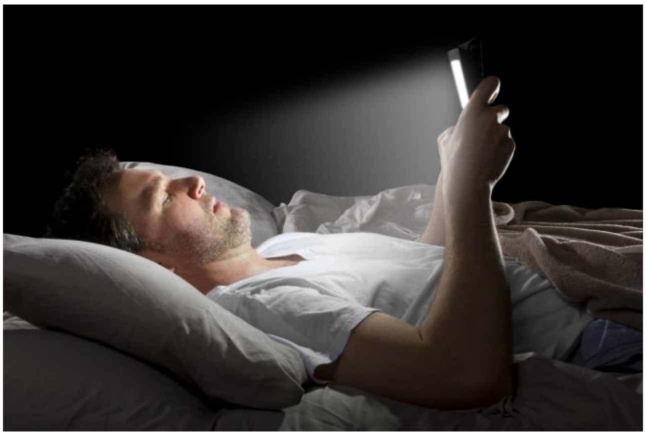
- **Light emissions from screens**

For most animals, melatonin production at the right time of day, is essential to a synchronised circadian rhythm and a good sleep pattern. When animals are exposed to light, even low levels of illumination, melatonin production is suppressed[146-148] and the circadian clock is delayed and pushed out of sync.[146,149] Exposure to light at different times of the day, using chronotherapy, can either delay or bring forward the circadian rhythm.[150,151]

At the same time as suppressing the synthesis of melatonin, exposure to light at night also has the effect of stimulating the brain and increasing levels of alertness and wakefulness.[152,153]

This is when we focus on electronic media and light emissions from their screens. Mobile phones, tablets, eReaders, entertainment consoles, TV's and laptops are all the culprits here and have been shown to affect sleep.[154] Mobile phones, tablets and eReaders especially as they tend to be held closer to the face, exposing higher intensity light to the retina. A research study from Harvard[155] discovered that when their test subjects used eReaders at night instead of reading paper books, on average, it increased sleep onset latency by 10 minutes and reduced melatonin production by half.

The intensity of the light emissions do play a part in this process also. For example, a higher intensity light at night, will have more pronounced affects on the circadian rhythm with other effects including a changed physiological and behavioural state,[156] especially during the early part of the night with blue light exposure.[157,158] Compared to light of lower intensity, high intensity light increases alertness, promotes wakefulness and stops the lowering of the core body temperature, all the things conducive to a good night's sleep.



Other studies have also shown that exposure to blue light emissions increases levels of alertness[159-162] as well as having a positive affect on cognitive functioning.[163-165]

Stephen Lockley, a sleep researcher at Harvard University, noted that light emissions with an intensity of 8 lux have an affect on circadian rhythms. This exceeds the lux intensity of most bedside table lamps.[166]

Research shows that each time our eyes are exposed to bright light, melatonin production is suppressed and this results in sleep disorders and a delayed sleep onset time.[167-169]

It’s not just any light that melatonin production is affected by. It’s most sensitive to light of a shorter wavelength, like blue light which we now know is emitted by the latest bedtime tech gadgets like mobile phones, tablets, television sets or anything with LED’s (light emitting diodes).[168,170]

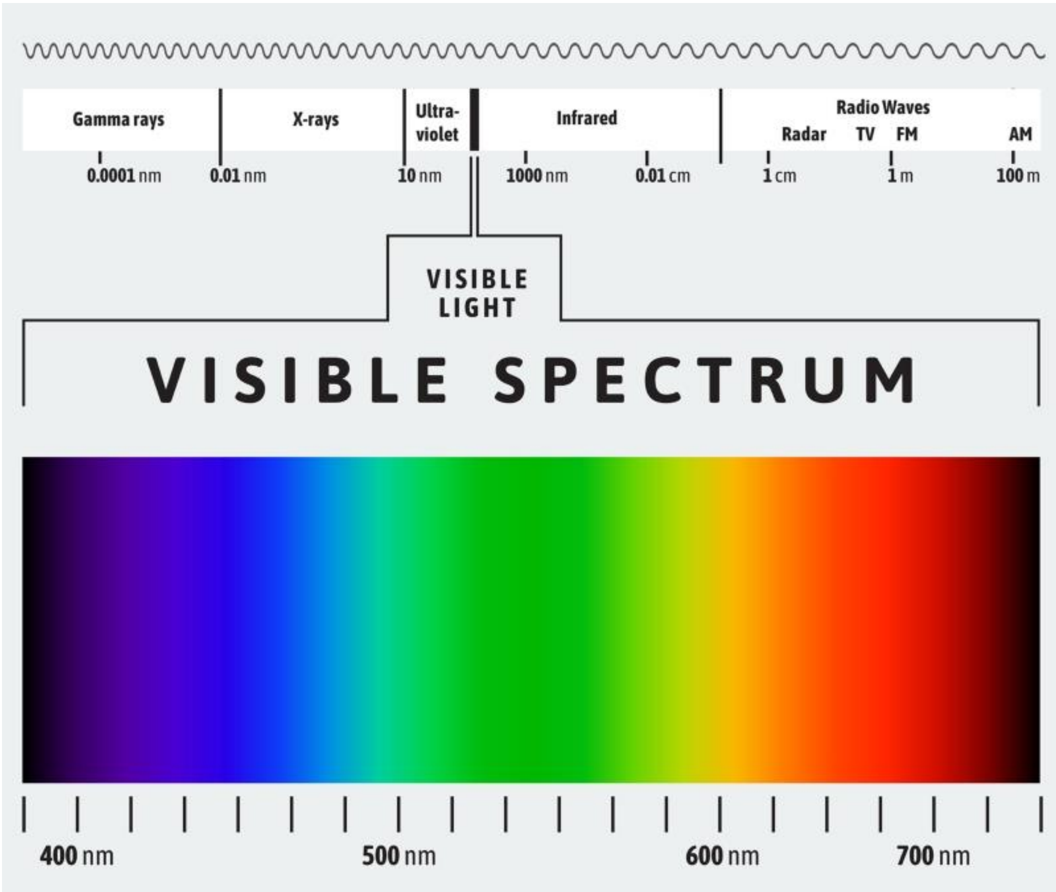
In 2017, a research sleep study[171] was undertaken at the University of Haifa in Israel led by PhD student Amit Shai Green. 19 people took part in the study, all aged in their 20’s. During this study, all subjects were required to spend 2 hours in front of a computer screen immediately before their bedtime. Green introduced the variable of having different light intensities for the different subjects. There were 4 different types of light in the study. Some of the computer screens emitted a more intense blue light, others a softer blue light, some an intense red light and others a softer red light. Red light was the control used in this study to assess the affects of blue light on the subject’s sleep.

It was recorded how many times the participants awoke during the night along with their total sleep time and time spent in REM sleep. A self-reported aspect of the study assessed how the participants felt the following morning after awaking.

It was shown that red light didn’t have anywhere near the same affect on sleep than the blue light. It was also discovered that those subjects who viewed the intense blue light before bedtime, had a reduced total sleep time of 16 minutes and awoke during the night more frequently compared to those who viewed screens emitting red light.

The study also indicated that those who were subjected to light exposure before bedtime suffered reduced production of melatonin, the sleep hormone which is normally secreted around 9pm. The effect of reduced melatonin synthesis before bedtime is an increased level of alertness which works against the body when trying to fall asleep. It was also found that blue light plays a greater part in the reduction of melatonin than red light.

Those exposed to bright light before bedtime also showed a reduction in the time spent during the REM sleep phase and a delayed REM sleep onset.



Blue light shown on the visible spectrum of light [172]

What is clear also is that the more electronic media devices that you're exposed to prior to falling asleep, the more of the affect on your sleep due to the accumulation of blue light emission exposure. If this exposure is continual, it can lead to an accumulated sleep debt over the week and chronic circadian rhythm disorders.

Several other independent research studies also identified that the secretion of melatonin affects the body's circadian rhythm and exposure to medium or bright intensity light does have a suppression effect on melatonin production.[173-177]

It has also been identified that blue light with a wavelength of 460 nm during night time is especially effective in being absorbed by melanopsin in the retinal ganglia cells, causing a delayed phase in the body's circadian rhythm and suppressing melatonin sythnthesis.[176-185]

The blue light spectral range of 460–480 nm has shown to be more effective in affecting circadian rhythms and suppressing melatonin compared to monochromatic light of the longer wavelength in the 555 nm range.[186,187]

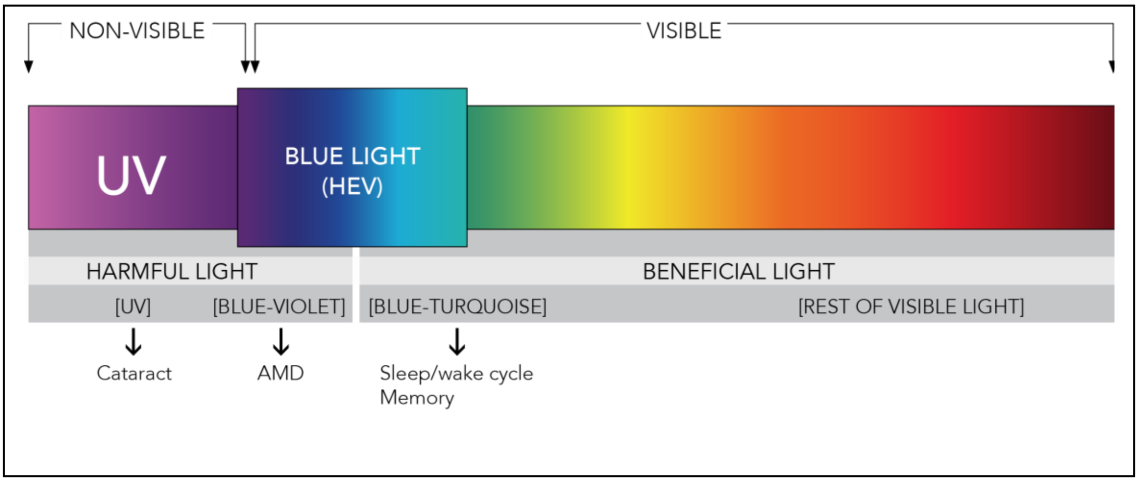
460 nm has been identified as the optimum wave length for the absorption of melanopsin in a separate study which also identified that night time exposure to blue light can affect circadian rhythms to the extent that it can change a person to being 'evening typed,' in other words, a night owl. It can also lead to additional psychological side effects.[188]

Mobile phone displays emit sufficient blue light to reduce the production of melanin during the night,[189] with significant affects on circadian rhythms noticeable when the light exposure is at night time.[190,191]

In a study conducted in June 2019 at the University of Bern in Switzerland,[192] neuroscientists were able to demonstrate that melanin-concentrating hormone neurons in the hypothalamus lengthened the REM sleep phase when subjects were sleeping in an environment with a comfortable temperature. This shows that melanin itself does have an effect on the body's circadian rhythm and light exposure can suppress its production.

Studies have been conducted into the different types of light emission and showed that even though the intensity of light from light emitting eBook readers is relatively low, it still has a significant affect on the suppression of melatonin and shifting the circadian rhythm to a later time.[146,155]

It's also been shown that exposure to shorter wavelength monochromatic light emissions, for example, from blue light, has a more pronounced affect on both circadian rhythms and alertness, than exposure to longer wavelength monochromatic light emissions, for example, from red light.[193-202] This is still the case when the shorter wavelength monochromatic light emissions are of a lower luminosity, in photopic lux, than longer wavelength emissions. As a result of these studies, we now know that photopic lux is not an effective measure of light affects on circadian rhythms but instead we should look to the wavelength of the light emissions.[203]



Studies have also been conducted into the affects of other colours of the light spectrum to compare the affects on both melatonin suppression and temporal shift of the circadian rhythm. In 2018, researchers at Harvard University[166] conducted one such study which compared the effects of 6 ½ hours of exposure to shorter wavelength blue light to the effects of 6 ½ hours of exposure to longer wavelength green light. The photopic lux remained the same for both light colours throughout the experiment. The results of the research study concluded that when exposed to the blue light, the suppression of melatonin occurred at a rate twice as long as it did in the subjects exposed to green light. Blue light emissions caused a temporal circadian rhythm delay of up to 3 hours, which was twice as much as the 1 ½ hours delay experienced in the subjects exposed to green light.

Let's turn our attention now to the commercial market in light-emitting diodes (LEDs). LED's have been in use in both commercial and residential settings for a couple of decades now.

They have been found to be more environmentally friendly both in terms of their raw materials and also their energy consumption. As a result, we have seen the widespread replacement of light bulbs with LED's in street lamps and other traffic signals all over the UK and in other environmentally-conscious countries. This increase in the adoption of LED's was due to their relatively low production costs and their size, making it possible to use them in more portable and miniature forms of technology.

In our homes, they're commonly found in our smart phones,[204] tablets, televisions, computer screens and entertainment systems. Although the LED light emissions appear white in colour, their actual emission colour can be in the blue light range from 400 to 490 nm.

White light LED's are available but they are essentially a bichromatic light created by mixing a blue light LED with a yellow phosphor which has a peak emission around 580 nm.[205] To the naked eye, this bichromatic light appears white in colour.[206] This type of LED is known as solid-state lighting (SSL). What we have seen however is a prevalence of shorter wavelength blue light, even in the RGB (red, green & blue) lighting systems and the SSL lighting.

The problem with these 'white' LED's are that over time, the yellow phosphor degrades through the natural process of phosphor bleaching.[207] This leads to a situation where over time, the colour temperature shifts to a more blue light with the blue light LED overpowering the resulting light spectrum and emitting further harmful blue light.

In order to minimise the harmful affects of blue light emissions, it's less harmful to favour LED's with light emissions between 470 and 480 nm on the spectral range, rather than those emitting shorter wavelength blue light below 450 nm.

- **Vision loss**

Research studies have focused on light emissions from electronic media devices, especially those from the shorter wavelength blue light spectrum. It has been shown that blue light can cause damage to photoreceptor retinal cells, possibly leading to age-related macular degeneration (AMD) and impaired vision in later life.[208]

Blue light contains more energy than the longer wavelength red and yellow light.

Professor Ajith Karunarathne from the University of Toledo, USA, who stated,

"*It's no secret that blue light harms our vision by damaging the eye's retina. Our experiments explain how this happens*."

Professor Karunarathne pointed out that there was no discernible affect from longer wavelength red, yellow or green light on the spectrum.

The same study highlighted that retinal photoreceptor cells don't regenerate and that blue light can lead to their destruction.

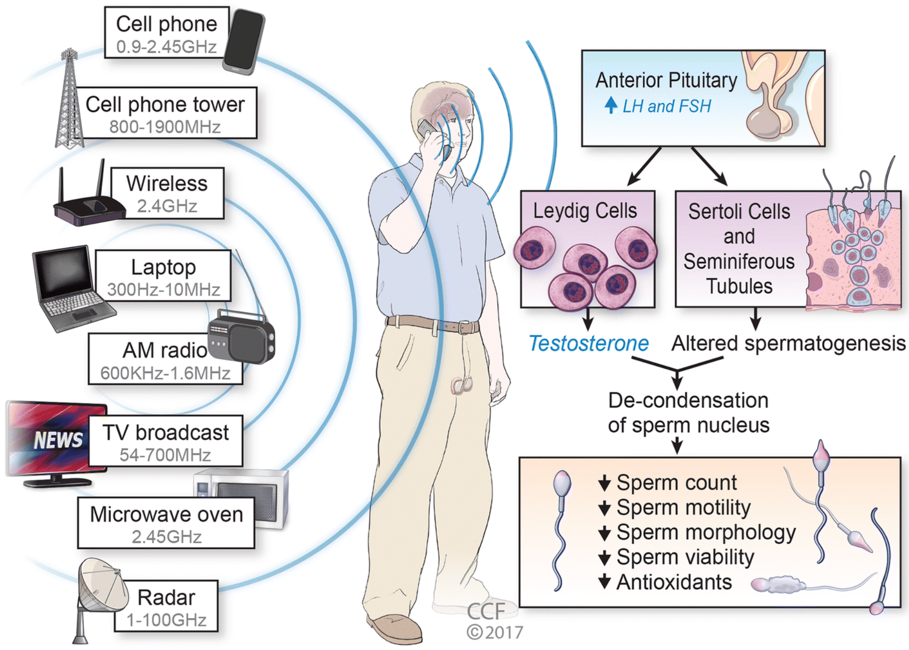
Studies have shown that the use of blue light blocking lenses and filters may provide some protection from age-related macular degeneration (AMD) as a result of accumulated blue light exposure.[209,210]

- **Electromagnetic radiation**

Looking specifically at mobile phones here as this is the form of technology that emits radiofrequency electromagnetic radiation. Phones transmit on the frequency around 900MHz. For around 20 years now, people have known that keeping mobile phones close to their head can result in headaches or other health issues.

As well as blue light emissions and psychophysiological stimulation, mobile phones also emit this electromagnetic radiation.

There have been several studies into the affects of radiofrequency electromagnetic radiation[144] on sleep or circadian rhythms. They discovered that the electromagnetic fields emitted by phones increases the frequency of sleep onset latency (SOL) and sleeping disorders and suppresses or delays the production of melatonin.[211-213]



Diagrammatic representation of various sources of EMF exposure [214]

There have also been some studies into the pulse-modulation effects of mobile phone signals on sleep and these have indicated that Extremely Low Frequency (ELF) pulse-modulated microwaves does affect sleep.[215]

Another research study indicated that mobile phones may be affecting sleep due to the thermal affects of the EMF disturbing the REM stage of sleep.[216]

A separate study from 2011 found that people exposed to mobile phone radiofrequency electromagnetic radiation showed an EEG increase in alpha brain waves whilst asleep and moderate impairment of stage 3 NREM sleep.[217]

- **Poor concentration and reduced memory**

Stage 3 NREM sleep otherwise known as the 'slow wave sleep' phase, is the sleep stage where all memories from the day are consolidated and processed. It's the restorative deep sleep phase that helps regeneration and recuperation of the body and the cognitive processes.

Disturbed sleep has been shown to adversely affect memory and reduce concentration rates. This clearly poses problems to adolescents who are undertaking studies at school with a resultant daytime inattentiveness and lack of productivity.

- **Affects on academic performance**

There have been several research studies into the affects of reduced sleep and academic performance, showing that reduced total sleep time can impair the potential for full intellectual functioning.[76]

It's become accepted that if a person experiences an extensive sleep deficit, their normal functioning will be impaired. Studies have identified that sleep deficit is a contributory factor in reduced academic performance for adolescents of high school and college age.[73-75]

A 2007 article entitled 'Snooze or Lose'[82,83] featured in the New Yorker Magazine summarised results from various sleep studies. The findings unanimously showed that total sleep duration in children was directly associated with their academic performance.

These studies showed that adolescent's brains are in a stage of development until approximately the age of 21 years. As most of this cognitive and memory development occurs during sleep, even a slight reduction in total sleep time may impair cognitive functioning.

The studies used standardised tests which showed those students who didn't get adequate sleep, scored on average 7 points lower. During class-time assessments, those students who slept one hour less, performed at a level equivalent to 2 years reduced cognitive development from their current level. The studies were also able to extrapolate the data providing a hypothesis that just 15 minutes of consistently extra sleep per night, was the difference between students receiving a grade 'A' instead of a grade 'B.'

In a 2015 research study conducted by Li et al.[119] they showed that the majority of the 516 graduate student respondents using mobile phones, showed decreased academic performance. They completed self-assessments of their mobile phone use, attentiveness, sleep characteristics and academic performance. Assessing the specific times of mobile phone use, it showed that for those student respondents who used mobile phones around bed time, they suffered reduced sleep quality. Those who admitted to using mobile phones during class times and study periods, were shown to have reduced academic performance.

A 2007 study by Yoo et al[8] found that just a single night of reduced sleep had an affect on the hippocampus, leading to a reduced ability to retain information.

Current studies show that the academic performance of adolescents can be affected by the '*synchrony effect*'[77] in the adolescent's circadian rhythm. This is what happens when circadian rhythms are at their peak and they're feeling very alert. When there is '*desynchrony*' in the circadian rhythm, academic performance is likely to be reduced.

Epidemiological studies[78] into sleep restriction have indicated that adolescents who have reduced sleep or suffer delayed sleep onset, can experience a wide degree of adverse effects on their academic performance, their health and even their safety. Other sleep studies have shown that there is a correlation between reduced academic performance and both reduced total sleep time and delayed sleep onset.[79-81] This is perhaps due to daytime somnolence with students feeling drowsy or nodding off in class or reduced attentiveness.

Other brain functions occurring within or associated with the prefrontal cortex,[218,219] have been shown to be adversely affected by a reduced total sleep time. These are things like attentiveness and higher functioning.

A 2017 study of college students conducted by Brigham and Women's Hospital[220] assessed circadian rhythms and sleep patterns, as well as any affects on academic performance. Their study concluded that patterns of behaviour built around sleep, for example a regular sleep routine, was just as important as the total sleep duration.

The study assessed sleep regularity over a 30 day period, observing 61 undergraduate students at Harvard College, using the sleep regularity index noted daily in respondent's sleep diaries.

Dr. Andrew Phillips, a Biophysicist at the Division of Sleep and Circadian Disorders who was the lead author of this study, stated,

"*Our results indicate that going to sleep and waking up at approximately the same time is as important as the number of hours one sleeps*."

He added,

"*Sleep regularity is a potentially important and modifiable factor independent from sleep duration*."

The study showed that of the students who had sleep pattern regularity, they also received better than average academic grades. This tended to indicate an inclination towards improved academic performance based on sleep regularity and not so much the total sleep time of the students.

For those students who suffered with irregularity of their sleep patterns, their circadian rhythms were discovered to be delayed by almost three hours.

Dr. Charles Czeisler, Director of the Sleep Health Institute at Brigham and Women's Hospital, stated in relation to this study,

"*For the students whose sleep and wake times were inconsistent, classes and exams that were scheduled for 9am were therefore occurring at 6am according to their body clock, at a time when performance is impaired. Ironically, they didn't save any time because in the end they slept just as much as those on a more regular schedule.*"

As well as a delayed circadian rhythm, those students with irregular sleep patterns experienced a 2.6 hours delay in melatonin production, compared to those with regular sleep patterns. It is this delayed melatonin release that allowed assessment of the circadian rhythm temporal desynchrony.

Dr. Phillips, the lead author of this study, added,

"*Using a mathematical model of the circadian clock, we were able to demonstrate that the difference in circadian timing between students with the most irregular sleep patterns and students with regular sleep patterns was consistent with their different patterns of daily light exposure*."

He went on to say,

"*In particular, regular sleepers got significantly higher light levels during the daytime, and significantly lower light levels at night than irregular sleepers who slept more during daytime hours and less during night time hours*."

A 2012 study[221] into grey matter morphometry of the brains of children and adolescents, showed that total sleep time during week days had an affect on the grey matter volume (GMV) of the bilateral hippocampal and right dorsolateral prefrontal cortex (DLPFC).

A previous study[222] from 2007 looked for a correlation between the sleeping patterns of a group of 177 adolescents and brain GMV, using both magnetic resonance imaging (MRI) and voxel-based morphometry (VBM).

The MRI scan provides detailed cross-sectional images of the brain tissue and brain stem. Whereas a VBM approach[222] shows differences in concentrations of brain tissue, through a voxel-wise comparison of multiple brain images. A voxel is like a pixel in three-dimensional space.

The 2007 study was born from three hypotheses. Firstly, that there would be a correlation between a reduced GMV in areas of the brain and shorter total sleep time, increased sleep onset latency, eveningness and later waking-up times at weekends. Secondly, that there would be a correlation between sleep behaviour and academic performance. Thirdly, that there was a correlation between sleep behaviour, academic performance and GMV in areas of the brain.

Other research studies[221,223] indicated that the most significant correlation between sleep quality and volumetric change in brain grey matter would be seen in the areas of the medial prefrontal cortex, the anterior cingulate cortex and the hippocampus. The three hypotheses were proven when it was observed that there was a correlation between delayed sleep onset during weekends and a reduced GMV in the frontal, anterior cingulate, and precuneus cortex regions of the brain. A correlation was also found between delayed sleep onset during weekends, reduced academic performance and a reduced GMV in the medial prefrontal cortex region of the brain. There was also found to be a correlation between a reduced total sleep time during weekdays and a reduced GMV in the frontal regions of the brain. There was an observed correlation between delayed wake-up times during weekends and a reduced GMV in the left frontal medial orbital cortex and the left anterior cingulate cortex regions of the brain.

They also identified a correlation between delayed sleep onset at weekends and reduced GMV in the right precuneus and paracentral lobule, the right middle/superior frontal gyrus and the right frontal superior medial cortex and left anterior cingulate cortex regions of the brain.

A correlation was observed between an increased total sleep time during weekdays and an increased GMV in the left superior and middle frontal gyrus regions of the brain.

Whilst showing positive correlations between GMV, total sleep times and academic performance, it is unclear in this study to what extent the variation of different sleep times could affect academic performance.

A previous study[224] showed a reduced GMV in the precuneus region of the brain in patients with insomnia, i.e.- those with reduced total sleeping times.

Interestingly, all these regions of the brain are crucial to things like multi-tasking,[225] which if impaired can itself affect academic performance.

- **Physical discomfort**

The use of any electronic media for a prolonged period of time can lead to some degree of physical discomfort.[226] This could be due to mild repetitive strain from constant texting using a mobile phone or perhaps sitting up awkwardly in bed, straining your neck and holding a controller, playing an entertainment console in bed at night.

- **Daytime tiredness**

In 2007 a research study was undertaken by Dr. Jan Van den Bulck in Belgium. He surveyed 1,656 adolescents and concluded that there was a positive correlation between mobile phone use by the adolescents and an increase in their daytime tiredness levels.[227]

Daytime tiredness may not just be due to late night mobile phone use. So the next time you feel sluggish and lethargic in the daytime, it may not be as people may tell you that you, 'Got out of the wrong side of bed.' It may just be that your circadian rhythm is suffering temporal desynchrony and had you stayed in bed and snoozed a few minutes longer, you would feel full of energy.

- **Other Serious Health Effects**

Animal and epidemiological studies have shown that disruption of the circadian rhythm and night time suppression of melatonin, may eventually lead to tumour growth.[228,229]

Other studies have implicated night time exposure to blue light as increasing the risk factor of breast and prostate cancer.[230-233]

In 2011, a new term was discovered called asynchronisation which looked at the effects of light exposure at different times on both children and adolescents.[234] It showed that sleep was disrupted by late night light exposure as a result of melatonin suppression and an altered circadian rhythm.

- **Irritability**

When your circadian rhythm is out of sync, it is likely to also make you feel irritable. To what degree depends upon how far out of sync you are and how much 'social jet lag' you are suffering.

Don't fight it. Just recognise this is your biochemistry and nature's way of trying to keep you healthy and safe.

- **Anxiety**

Studies have been conducted into the effects of mobile phone use and the associated psychological conditions. Studies have shown that sleep disorders are prevalent in those who exercise high mobile phone use or exhibit the constant need to engage and be connected with peers.[235]

A 2016 study of Belgium adults aged 19 – 94 years old,[236] showed a further correlation between mobile phone use at bedtime and an increased rate of anxiety disorders, including depressive episodes, daytime somnolence, stress and delayed sleep onset.

For adolescents who have a need to remain constantly connected, the anxiety of not having access to their devices or not receiving notifications, can be very real and manifest itself in sleep disorders.

Another 2016 study looked at 700 college students and separated them from their smart phones. The majority of the students experienced anxiety and suffered night time awakenings as a result of supressed melatonin production and cortisol accumulation.[237]

METHODOLOGY

- **Ethical Treatment**

Before administrating the questionnaires to adolescents in the academic setting, each respondent was given a written explanation at the top of the questionnaire, detailing the concepts and purposes of the study and stated that their answers would be used only for research purposes.

All of the procedures performed in this research study involved human participants. This study has been officially given a NHS Integrated Research Application System (IRAS) project ID number: 275915.

The Medical Research Council (MRC) NHS Health Research Authority questionnaire I completed in respect of this study, confirmed that this study would be classed by the MRC as '*Research*.'

The Medical Research Council (MRC) NHS Health Research Authority questionnaire I completed in respect of this study confirmed that I did not require NHS Research Ethics Committee (REC) approval prior to going ahead with this research project, provided that the research is only conducted in England, which it is.

All aspects of this study were carried out in accordance with current ethical standards and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

- **Participants and Procedure (demographics & setting)**

864 adolescents, aged between 11 and 17 years old, from 3 academic establishments took part in this research study. The main independent variables in the study were type and frequency of electronic devices used at bedtime, hours of sleep during both weekdays and weekends, sleep quality and daytime attentiveness.

Members of the teaching faculty at the partaking academic institutions distributed a two-page questionnaire by hand to all students present in their classes. These faculty members informed their students that participation was both anonymous and voluntary. Students were given the questionnaire to complete during either a form registration period or class time in order to expedite collection of the data samples and to maintain a relatively quiet and controlled environment in which the questionnaires can be completed.

- **Instruments for Data Collection (questionnaire)**

Surveys utilised a self-reported assessment of 5 domains: sleep pattern; Sleep quality; Sleep environment; Technology and Circadian rhythm.

To analyse adolescent ***sleep patterns***, I characterised them by asking:

(1) bedtime; time taken to fall asleep; wake-up time; & Out of bed time. Obtaining separate data for both weekdays and weekends, also provided the overall hours of sleep per night;

(2) whether the respondent considered themselves a 'night owl' or 'morning person;'

(3) whether they felt they could have slept for longer;

(4) time taken to fall asleep.

Diagram showing morning-typed person versus evening-typed person [238]

To analyse adolescent ***sleep quality***, I characterised them by asking:

(1) how they would rate their own sleep quality over the last month;

(2) whether they felt they could improve the quality of their sleep;

(3) whether they suffered from any of the listed common sleep disorders;

(4) whether they have visited a doctor before about their sleep or a daytime alertness problem;

(5) whether they have taken any medication to help them sleep during the last month;

(6) whether they require an alarm clock or someone else to help them wake up in the mornings;

(7) whether, during the last month, they have had trouble sleeping because of any of the listed issues. There are 10 listed issues, each with a 4-point Likert-type scale to establish frequency of the issue.

To analyse adolescent *sleep environment*, I characterised them by asking:

(1) whether they share a bedroom with another person;

(2) whether the respondent usually falls asleep with music or the TV on;

(3) whether the respondent usually falls asleep with the bedroom light switched on;

(4) where exactly they put their mobile phone when they go to bed;

(5) whether they respond to phone notifications when falling asleep & if so, how quickly.

To analyse adolescent *bedtime technology* use, I characterised them by asking:

(1) at what age they received their first mobile phone;

(2) how often they delay their bedtime due to some form of technology;

(3) whether they feel anxious when separated from their mobile phone or tablet;

(4) whether they feel the need to be accessible by phone or tablet 24 hours a day & if so, what degree of stress does that cause them (on a 4-point Likert-type scale);

(5) whether they have previously tried to reduce their technology use in the bedroom late at night & if so, whether they were successful;

(6) whether they felt that electronic devices affected their sleep in any way;

(7) which types of bedtime technology the respondent felt were stopping them from getting an adequate amount of sleep.

To analyse adolescent *circadian rhythms*, most of the responses used a 4 or 5-point Likert-type scale. I characterised these responses by asking:

(1) how they felt their quality of sleep affects their mood, energy levels and relationships;

(2) how they felt their quality of sleep affects their concentration, productivity and ability to stay awake;

(3) how often they feel they have trouble getting to sleep;

(4) how often they feel they lie awake at night with their mind racing, feeling worried, anxious or depressed;

(5) whether they usually awake feeling tired or sluggish;

(6) whether they usually awake feeling irritable or angry;

(7) how often the respondent feels drowsy or unrefreshed during the daytime;

(8) how often, during the last month, have they had trouble staying awake in school, eating meals or engaging in social activity;

(9) whether they feel their school performance may have suffered because of sleepiness;

(10) how much of a problem, if at all, during the last month, have they had with keeping up enough enthusiasm to get things done;

(11) at what time, on a normal school day, they would prefer to rise;

(12) at what time, on a normal school day, they would prefer to go to bed;

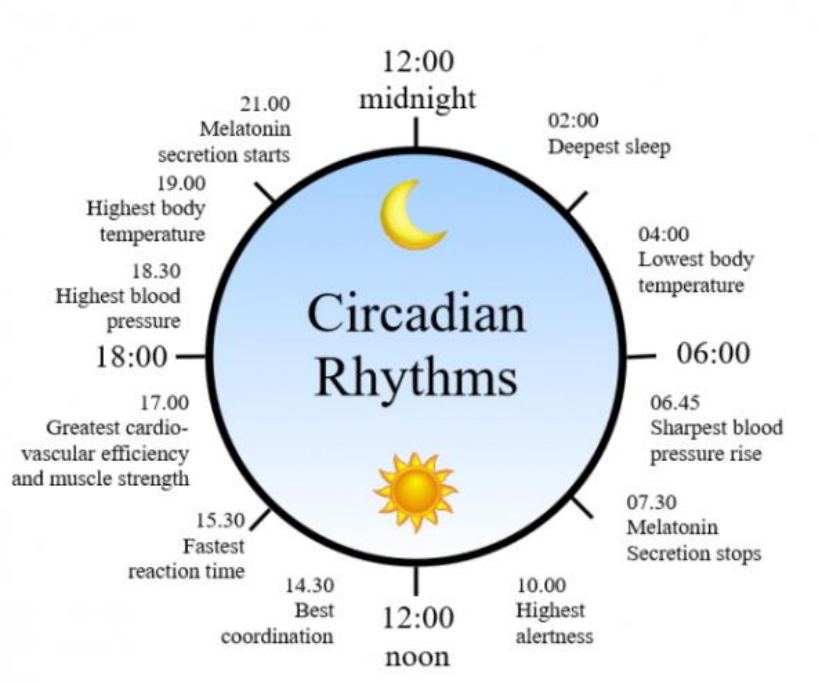
(13) how easy they would find it to always go to bed at midnight;

(14) how easy they would find it to always awake at 6am;

(15) at what time the respondent usually felt the first signs of tiredness and the need for sleep;

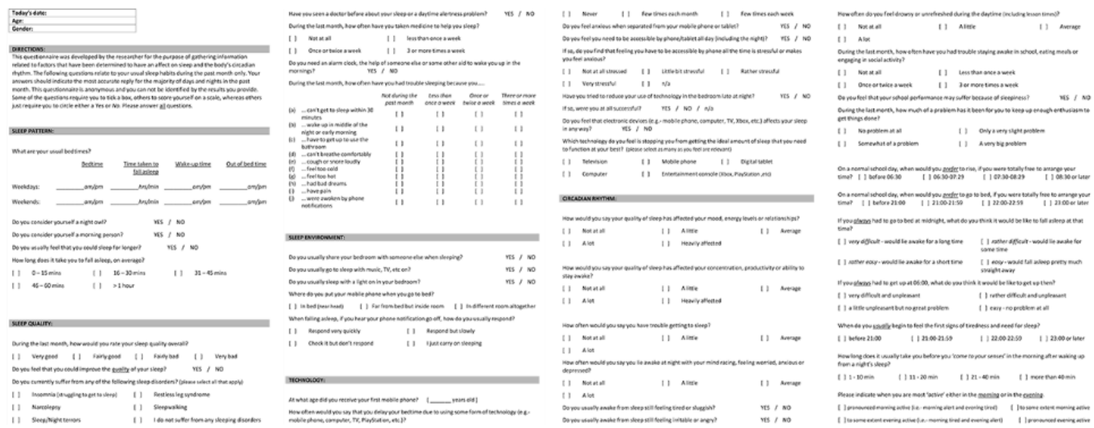
(16) how long it usually takes for the respondent to 'come to their senses' each morning after waking up;

(17) whether they feel they are most active either in the morning or the evening.



- **The Pilot test**

A pilot test of the questionnaire was administered to a group of 8 students. The students' responses and feedback were used to assess the questionnaire on its question readability, clarity, format, and length. Additionally, this pilot group of students were surveyed for their thoughts on peer willingness to complete the questionnaire. Feedback collected from the pilot group was assessed and adjustments were made to some of the wording of the questions just to make them more easily readable at high speed. Additional questions were also added to assess various aspects of circadian rhythm. This lead to a four-page questionnaire tool with 43 questions that required approximately 6 min for completion.



This pilot study was conducted to ensure face validity of the questionnaire. No further validation was conducted with the revised questionnaire. Those students who participated in the pilot test were anonymous and once they had completed the additional questions, also had their data responses included within the research data sample.

- **Measures**

The 5 various domains were assessed using a combination of questions from various studies along with some newly developed questions.

I looked at establishing whether each respondent had a morning or evening disposition. To do this I incorporated questions with a Likert-type scale from *The Diurnal Type Scale* constructed by Torsvall & Åkerstedt (1980).[239]

I turned to the *Bergen Insomnia Scale* (BIS)[240] to look for ways to identify features of insomnia and other aspects that may be experienced by the respondents late into the night. Some of the questions from the BIS were re-worked to allow for relevancy to this study.

My survey also incorporated aspects of the Pittsburgh Sleep Quality Index (PSQI). The original, full-length version of the PSQI was developed by Buysse et al. (1989).[241] It consisted of 24 questions, including a self-reported survey consisting of 19 items quantifying sleep quality and disturbances over the respondent's past month and 5 additional questions which may be answered by someone who lives with the respondent. Only the self-rated questions were included in the original survey analysis.

The questions in the PSQI were grouped into seven key 'components' of sleep quality (i.e. subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication and daytime dysfunction). The responses are weighted on a 4 point Likert scale. Each component is assigned a value of 0-3 points. The seven component scores were summed up, yielding a global index score ranging from 0 to 21, with '0' indicating very good sleep quality and '21' indicating severe difficulties in all areas of sleeping.[241]

A global index score of 5 or greater indicates poor sleep quality, while less than 5 indicates good sleep quality. In this survey, only the self-rated questions were used as the data collection occurred during school time.

The PSQI has internal consistency and a reliability coefficient (Cronbach's alpha) of 0.83 for its seven components. A Cronbach's alpha score over 0.70 is considered to show high internal consistency and validity. Numerous studies using the PSQI indicate its high validity and reliability.

In this research study, in addition to the PSQI and other validated questions, I asked for further information in order to determine more information containing demographic variables such as age and gender.

Long Sleep Onset Latency (SOL) is usually defined as 31 min or more in adults,[242] but as adolescents may experience longer SOL due to biologically based delayed circadian rhythms occurring during puberty,[243] I decided to use a cut-off of 60 min.

STATISTICAL ANALYSIS

The data obtained from this study was evaluated using the IBM SPSS (build 1.0.0.1327) program.

For statistical analysis of the data, Pearson's Correlation Coefficient, *t* - test, *Kruskal-Wallis* test and Stepwise Multivariate Linear Regression Analysis were all used.

Tests for significance were two-tailed and *p* values of <0.05 were assumed to represent statistical significance.

- **Software package used for analysis**

  IBM SPSS Statistics 26 for Windows (SPSS Inc, Chicago, Illinois, USA) was used for all analyses.

  SPSS originally stood for 'Statistical Package for the Social Sciences.'

  I chose this particular software package for statistical analysis because it has often been mentioned in many of the research studies I came across, as the tool most used for analysis.

  SPSS Statistics is favoured by market researchers, health researchers, survey companies, the government, education researchers, marketing organisations and other bodies wishing to manipulate tabled data for analytical purposes.

- **<u>Variables</u>**

In total there were 62 variables entered into SPSS for analysis. Each respondent was anonymised and allocated a URN (Unique Reference Number) to cross-reference against their survey instrument response sheet.

The questionnaires responses were converted into numerical values, for example, for gender, I entered '*1*' for male and '*2*' for female. For questions where respondents had to provide subjective responses, for example, '*rarely*,' '*frequently*' and '*all the time*,' these were allocated a corresponding Likert scale number from 1 to 3.

- **<u>Models used</u>**

  - **<u>Cronbach's alpha:</u>** *Cronbach's Alpha* is most commonly used when assessing the internal consistency of a questionnaire (or survey) consisting of multiple Likert-type scales and other items. It's an index of reliability.
  - **<u>Pearson's Correlation Coefficient:</u>** The Pearson correlation coefficient, also referred to as Pearson's *r*, the Pearson product-moment correlation coefficient or the bivariate correlation, is a measure of the linear correlation between two variables. In other words, the strength of the association between two given variables.
  - **<u>t - test:</u>** The *t*-test is used to establish if the correlation coefficient is significantly different from zero, and, hence that there is evidence of an association between the two variables. In other words, how statistically significant the association is between the variables.

- **Kruskal-Wallis test:** The *Kruskal-Wallis H test*, sometimes also referred to as the '*one-way ANOVA on ranks test*', is a rank-based nonparametric test that can be used to determine if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable.
- **Stepwise Multivariate Linear Regression Analysis:** This is a method of regressing multiple variables in SPSS while simultaneously removing those that aren't important. Essentially it does multiple regressions a number of times, each time removing the weakest correlated variable. It is used to measure the degree at which multiple independent variables (predictors) and more than one dependent variable (responses), are linearly related.

- **Exclusion criteria**

Exclusion criteria included respondents that fell outside the specified age range (11-18 years of age).

Sleep variables were checked for validity of answers, resulting in partial data samples from 8 participants being excluded due to obvious invalid responses.

Adolescents who reported that they used bedtime technology and did not have any psychological, neurological, respiratory sleep problems or other notable sleep disorders were included in the survey.

Individuals with clinically diagnosed or suspected neurological or psychological conditions that would have nevertheless impaired their daytime attentiveness or circadian rhythms were not included in this study.

RESULTS

In this section, we review all of the responses from the survey instrument that I sent out to the various participating schools across Greater Manchester.

This consisted of basic analysis of the survey responses, followed by more advanced statistical analysis using various models to interrogate the data responses, looking for statistically significant correlations between the various data variables (question responses).

General

- Total number in this voluntary study was 864. This was a mixture of adolescents, drawn from both multi and single-sex schools from different areas reflecting a wide distribution of socio-economic and racial backgrounds.

- The respondent's ages in this research study range from 11 to 17 years old. The average age of the respondent, based on numbers in the data sample of each age demographic was 13.67 years old (± 1.34 years), representing adolescents of secondary school age, generally situated between academic years 8 and 9.

- 41.7% of the respondents were male (n= 360) and 58.3% of the respondents were female (n= 504). Whilst some respondents identified as '*non-binary*,' they did nevertheless chose their birth gender.

<u>Sleep Pattern</u>

- The average sleep duration was 8.01 ± 1.2 hours if there was no school the next day. If we remove the statistical aberrations from Sleep Duration and Time of Waking Up, we get slightly different figures. These aberrations are the extremes that could either represent extraordinary circumstances for that individual respondent or they might have answered incorrectly. When we removed these aberrations, the new Average Sleep Duration is 8 hours 10 mins and the new Average Time of Waking Up is 06:48Hrs. What is apparent, however, is that there are different average sleep durations per age group.

	Time of Going To Sleep	**Time of Waking Up**	**Sleep Duration**	**Time Taken to Get To Sleep**
Mean Average	22:49	06:50	8hrs 1 min	42 mins
Minimum	19:05	05:00	2 hrs 25 mins	0 mins
Maximum	03:35	11:00	10 hrs 40 mins	5 hrs

- 49.2% (n= 425) of the respondents considered themselves to be a '*nightowl*,' whereas 32.5% (n= 281) of the respondents considered themselves to be a '*morning person*.' This indicates a tendency towards '*eveningness*' which is what we would expect from the biochemical and hormone processes that the adolescent body undergoes with a slightly delayed circadian rhythm.

- 78.3% (n= 677) of the respondents felt that on a usual basis, they could sleep for longer. This indicates a very high tendency towards an accumulation of sleep debt over the week.

- The majority of respondents, 72.5% (n= 626) took 16 minutes or longer to fall asleep. 35% (n= 302) of the respondents took between 16 to 30 minutes to fall asleep once they had committed to going to sleep during their bedtime routine. 15.8% (n= 137) of the respondents took over 1 hour to fall asleep. These figures would tend to suggest a prevalence towards *Sleep Onset Latency*.

How long to fall asleep?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-15 mins	238	27.5	27.5	27.5
	16-30 mins	302	35.0	35.0	62.5
	31-60 mins	187	21.7	21.7	84.2
	> 1 hour	137	15.8	15.8	100.0
	Total	864	100.0	100.0	

Sleep Quality

- Respondents were asked how they rated their overall sleep quality over the previous month. 7.5% (n= 65) rated their sleep quality as very bad; 25.8% (n= 223) rated their sleep quality as fairly bad; 55% (n= 475) rated their sleep quality as fairly good; and 11.7% (n= 101) rated their sleep quality as very good. This indicates a third (33.3%) of the respondents felt unhappy with their overall sleep quality, classifying it as bad.

- When asked whether they felt they could improve the quality of their sleep, interestingly 70.8% (n= 612) felt that they could improve their quality of sleep. This is indicative of the fact that majority of the respondents are aware that they have some sleeping issues and this would normally show in symptoms experienced either during the night itself or the following daytime.

- Respondents were asked whether they suffered with any of the following sleeping disorders: Insomnia; Narcolepsy; Night terrors; Restless leg syndrome; and Sleepwalking. 17.5% (n= 151) respondents suffer with at least 1 sleeping disorder, with 5% (n= 43) suffering with 2 or more sleeping disorders, indicating almost a quarter of the respondents surveyed suffer with a sleeping disorder.

- 7.5% (n= 65) of the respondents had visited a doctor regarding their sleep or a daytime alertness problem.

- Respondents were asked how often they had taken medication to help them sleep over the previous month. The majority, 95.8% (n= 828) reported not having taken any medication.

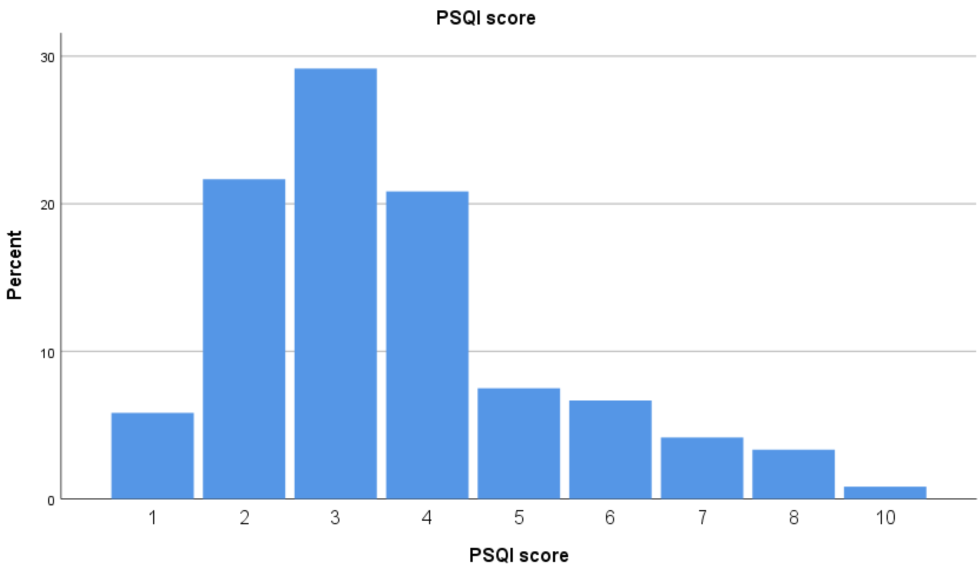
- 82.5% (n= 713) of the respondents indicated that they need an alarm clock, the help of someone else or some other aid in order to wake them up in the mornings.

- While 39.2% (n= 338) of the respondents have not been awoken by mobile phone notifications, the majority (60.9%) had been awoken during sleep. 12.5% (n= 108) were awoken less than once-a-week; 19.2% (n= 166) were awoken once or twice-a-week and 29.2% (n= 252) were awoken 3 or more times-a-week. This in itself proves that ready access to bedtime technology does in fact disturb sleep.

- The average score for total PSQI was 3.62 ± 1.76. The minimum score was 1, representing excellent sleep quality). The maximum PSQI score was 10. According to these PSQI scores, 22.5% (n= 194) of the adolescents participating in the study had poor quality sleep (a total PSQI score of 5 or more was associated with poor sleep quality). This indicates that almost a quarter of the respondents had a prevalence towards poor quality sleep.

PSQI score

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	50	5.8	5.8	5.8
	2	187	21.7	21.7	27.5
	3	252	29.2	29.2	56.7
	4	180	20.8	20.8	77.5
	5	65	7.5	7.5	85.0
	6	58	6.7	6.7	91.7
	7	36	4.2	4.2	95.8
	8	29	3.3	3.3	99.2
	10	7	.8	.8	100.0
	Total	864	100.0	100.0	



Sleep Environment

- A majority of the respondents 81.7% (n= 706) indicated that they do not share their bedroom with someone else when sleeping.

- 21.7% (n= 187) of the respondents replied to suggest they usually go to sleep with the music, TV or other external electronic device playing. We know already that certain types of audio or visual content can over-stimulate the mind and cause anxiety or the fight-or-flight syndrome, increasing sleep onset latency.

- Only 12.5% (n= 108) of the respondents indicated that they usually sleep with the light on in their bedroom, whereas 86.7% (n= 749) of the respondents indicated that they did not.

- When asked where do they put their mobile phone when they go to bed each night, 39.2% (n= 338) said they keep their phones in bed with them, near their head; 40% (n= 346) said they keep their phones inside their bedroom but far from their bed; and 20.8% (n= 180) of the respondents said they keep their phone in a different room altogether. This indicates a high degree of respondents who are open to being disturbed in their sleep or prone to sleep onset latency due to the presence of their mobile phone in bed with them. We already know that 60.9% are awoken during their sleep by their mobile phone notifications. This is no surprise considering that 39.2% keep their phones in bed with them, near their head.

Where do you put your mobile phone?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	In bed (near head)	338	39.2	39.2	39.2
	Far from bed but inside room	346	40.0	40.0	79.2
	In different room altogether	180	20.8	20.8	100.0
	Total	864	100.0	100.0	

- Respondents were asked how they usually react if they hear their phone notifications when falling asleep. 7.5% (n= 65) said they respond very quickly; 6.7% (n= 58) said they respond but slowly; 27.5% (n= 237) said they check their phone but don't respond; and 58.3% (n= 504) of the respondents said they just carry on sleeping. This survey response indicates that almost a third of the respondents check their phones but don't respond. However, more significantly it indicates that of the 864 respondents in this research study, 41.7% (360) will actively check their phone when falling asleep to read their notifications.

How do you respond to phone notifications?

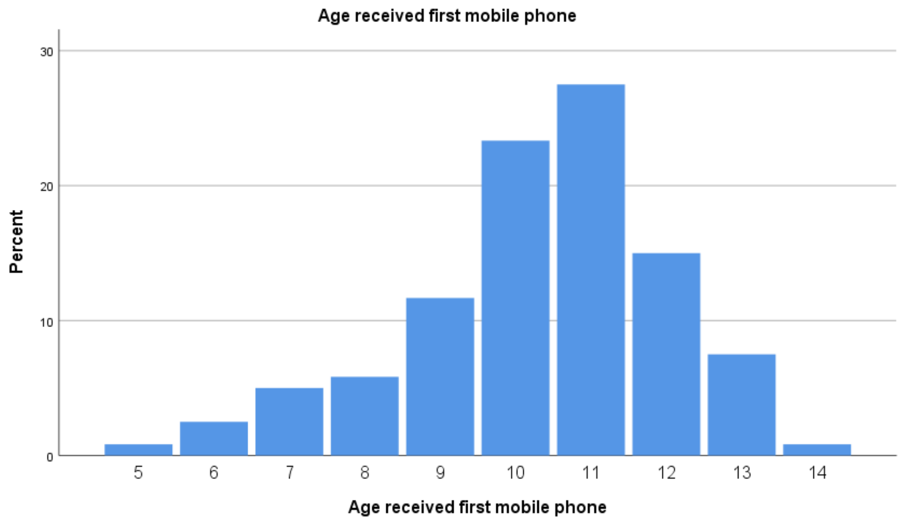
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Respond very quickly	65	7.5	7.5	7.5
	Respond but slowly	58	6.7	6.7	14.2
	Check it but don't respond	237	27.5	27.5	41.7
	Just carry on sleeping	504	58.3	58.3	100.0
	Total	864	100.0	100.0	

Technology

- The majority of respondents, 27.5% (n= 237) indicated that they received their first mobile phone at the age of 11 years old. The minimum age was 5 years old and the maximum age for receiving their first mobile phone was 14 years old. The mean average age was 10.3 years old (SD = 1.738) which is Year 6, the final year of primary school. All respondents stated that they have a mobile phone or have access to one that they use on a regular basis.

Age received first mobile phone

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	7	.8	.8	.8
	6	22	2.5	2.5	3.3
	7	43	5.0	5.0	8.3
	8	50	5.8	5.8	14.2
	9	101	11.7	11.7	25.8
	10	202	23.3	23.3	49.2
	11	237	27.5	27.5	76.7
	12	130	15.0	15.0	91.7
	13	65	7.5	7.5	99.2
	14	7	.8	.8	100.0
	Total	864	100.0	100.0	



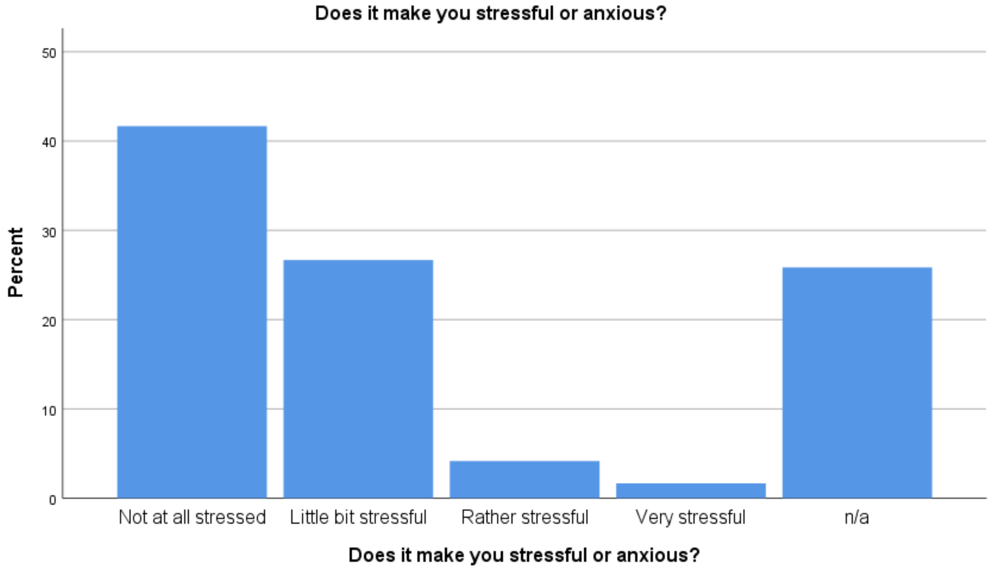
- 20.8% (n= 180) of respondents had never delayed their bedtime in order to use some form of bedtime technology (e.g.- mobile phone, computer, TV, PlayStation, etc). However, 37.5% (n= 324) delayed their bedtime a few times each month and 41.7% (n= 360) stayed awake longer a few times each week in order to use bedtime technology. This indicates a prevalence to delay bedtime, specifically in order to use some form of bedtime technology.

- A third of respondents, 32.5% (n= 281) stated that they felt anxious when separated from their mobile phone or tablet and just over a third of respondents, 36.7% (n= 317) stated that they needed to be accessible by phone or tablet all day (including at night). This is indicative of a high-dependency on mobile phones.

- 41.7% (n= 360) of the survey respondents viewed accessibility via mobile phones to be not at all stressful with a third, 32.6% found it to be stressful and made them feel anxious. 26.7% (n= 230) found it to be a little bit stressful; 4.2% (n= 36) found it to be rather stressful and 1.7% (n= 14) found it to be very stressful. The 224 respondents (25.8%) who replied '*n/a*' didn't feel they needed to be accessible by phone all the time.

Does it make you stressful or anxious?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all stressed	360	41.7	41.7	41.7
	Little bit stressful	230	26.7	26.7	68.3
	Rather stressful	36	4.2	4.2	72.5
	Very stressful	14	1.7	1.7	74.2
	n/a	224	25.8	25.8	100.0
	Total	864	100.0	100.0	



- 20% (n= 173) had previously tried but were unsuccessful in reducing their use of bedtime technology late at night.

Tried to reduce use of technology? * If so, was it successful?

		If so, was it successful?			
		Yes	No	n/a	Total
Tried to reduce use of technology?	Yes	324 *(37.5%)*	173 *(20%)*	29 *(3.3%)*	526
	No	14 *(1.7%)*	43 *(5%)*	274 *(31.7%)*	331
Total		338	216	303	857

- Just under half of the respondents, 44.2% (n= 382) said that they felt that electronic devices (e.g.- mobile phone, computer, TV, Xbox, etc) affected their sleep.

Do electronic devices affect your sleep?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	382	44.2	44.2	44.2
	No	482	55.8	55.8	100.0
	Total	864	100.0	100.0	

- From the survey responses, it was clear that 67.5% (n= 583) respondents felt that mobile phones were the form of technology that was most associated with stopping them getting the ideal amount of sleep. The television was the next form of technology that stopped respondents from getting their ideal amount of sleep with 18.3% (n= 158) providing that as a response.

	Television	**Mobile phone**	**Digital tablet**	**Computer**	**Entertainment Console**
Yes	158 *(18.3%)*	583 *(67.5%)*	50 *(5.8%)*	65 *(7.5%)*	115 *(13.3%)*
No	706 *(81.7%)*	281 *(32.5%)*	814 *(94.2%)*	799 *(92.5%)*	749 *(86.7%)*

Circadian Rhythm

- 73.3% of the respondents stated that they felt their quality of sleep has affected their mood, energy levels or relationships. 40.8% (n= 353) felt it had been affected a little. 9.2% (n= 79) felt that their mood has been heavily affected. This indicates a very high dependency between sleep quality and mood and energy levels the following day.

Affected mood?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	230	26.7	26.7	26.7
	A little	353	40.8	40.8	67.5
	Average	144	16.7	16.7	84.2
	A lot	58	6.7	6.7	90.8
	Heavily affected	79	9.2	9.2	100.0
	Total	864	100.0	100.0	

- 75% of the respondents stated that they felt their concentration, productivity or ability to stay awake has been affected by their quality of sleep. 40.8% (n= 353) stated that they felt it has been affected a little by their quality of sleep. 11.7% (n= 101) felt that their concentration has been heavily affected.

Affected concentration?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	216	25.0	25.0	25.0
	A little	353	40.8	40.8	65.8
	Average	86	10.0	10.0	75.8
	A lot	108	12.5	12.5	88.3
	Heavily affected	101	11.7	11.7	100.0
	Total	864	100.0	100.0	

- 74.2% of the respondents stated that they had trouble getting to sleep. 40.8% (n= 353) stated that they had trouble getting to sleep a little. 18.3% (n= 158) felt that they had have trouble getting to sleep a lot.

Trouble getting to sleep?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	223	25.8	25.8	25.8
	A little	353	40.8	40.8	66.7
	Average	130	15.0	15.0	81.7
	A lot	158	18.3	18.3	100.0
	Total	864	100.0	100.0	

- 65% of the respondents stated that lie awake at night with their mind racing, feeling worried, anxious or depressed. 35.8% (n= 310) stated that lie awake at night a little with their mind racing, feeling worried, anxious or depressed.

Lying awake at night?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	302	35.0	35.0	35.0
	A little	310	35.8	35.8	70.8
	Average	101	11.7	11.7	82.5
	A lot	151	17.5	17.5	100.0
	Total	864	100.0	100.0	

- 67.5% (n= 583) of respondents reported awaking from sleep feeling tired or sluggish.

- Just under a third, 30.8% (n= 266) of respondents reported awaking from sleep feeling irritable or angry.

- 80% of the respondents stated that they felt drowsy or unrefreshed during the daytime. 42.5% (n= 367) reported feeling a little drowsy. 15.8% (n= 137) reported feeing drowsy a lot of the time.

- 47.5% of the respondents said that during the previous month, they had trouble staying awake in school, eating meals or engaging in social activity. 20.8% (n= 180) said this occurred but less than once-a-week. 10% (n= 86) said this occurred 3 or more times-a-week.

- Over a third, 37.5% (n= 324) of the respondents said that they felt that their school performance may suffer because of sleepiness.

- 60.8% of respondents reported that during the previous month, there have been problems keeping enough enthusiasm to get things done. 34.2% (n= 295) said they felt it only a very slight problem, whereas 6.7% (n= 58) felt it was a very big problem.

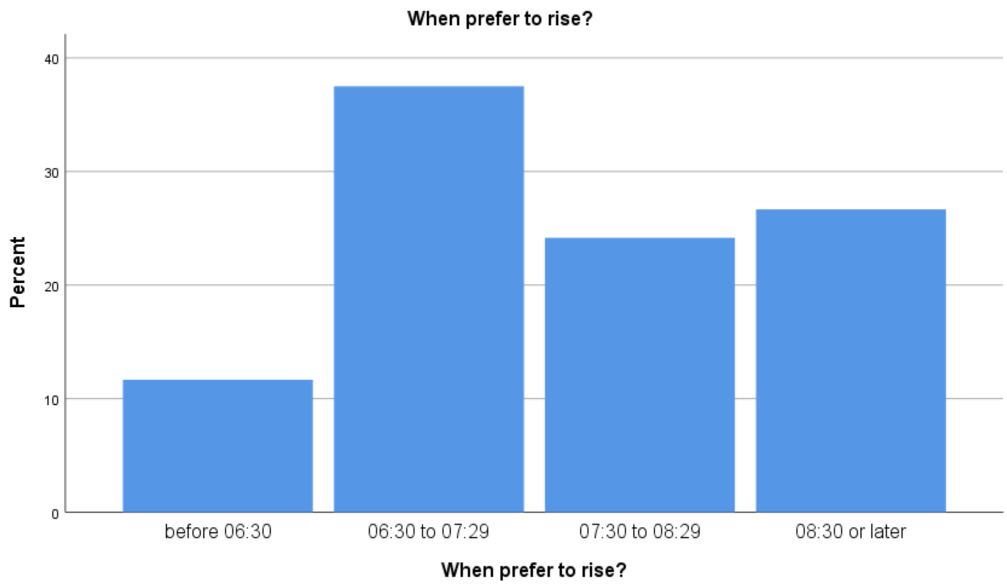
Levels of Enthusiasm

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No problem at all	338	39.2	39.2	39.2
	Only a very slight problem	295	34.2	34.2	73.3
	Somewhat of a problem	173	20.0	20.0	93.3
	A very big problem	58	6.7	6.7	100.0
	Total	864	100.0	100.0	

- 37.5% (n= 324) stated that if they were totally free to arrange their own time, they would prefer to rise between 6.30am and 7.29am.

When prefer to rise?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	before 06:30	101	11.7	11.7	11.7
	06:30 to 07:29	324	37.5	37.5	49.2
	07:30 to 08:29	209	24.2	24.2	73.3
	08:30 or later	230	26.7	26.7	100.0
	Total	864	100.0	100.0	



- 38.3% (n= 331) stated that if they were totally free to arrange their own time, they would prefer to go to bed between 10pm and 10.59pm.

When prefer to go to bed?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	before 21:00	65	7.5	7.5	7.5
	21:00 - 21:59	317	36.7	36.7	44.2
	22:00 - 22:59	331	38.3	38.3	82.5
	23:00 or later	151	17.5	17.5	100.0
	Total	864	100.0	100.0	

- Respondents were asked, if they always had to go to bed at midnight, what they thought it would be like to fall asleep at that time. The majority of people, 29.2% (n= 252) felt that it would be easy and they would fall asleep pretty much straight away. 14.2% (n= 122) felt that they would find it very difficult and they would lie awake for a long time.

- Respondents were then asked if they always had to get up at 6am, what they think it would be like to get up at that time. 30.8% (n= 266) said they would find it rather difficult and unpleasant. 17.5% (n= 151) said they would find it easy with no problem at all.

- Exactly a third, 33.3% (n= 288) felt that they usually begin to feel the first signs of tiredness and need for sleep between 9pm and 9.59pm.

- 41.7% (n= 360) of the respondents said it usually took them between 11 and 20 minutes before they 'come to their senses' in the morning after waking up from a night's sleep. 12.5% (n= 108) adolescents reported taking more than 40 minutes to 'come to their senses' in the morning after waking up.

- All respondents were asked whether they were most active either in the morning or the evening. 77.5% (n= 670) replied indicating that they were '*evening-typed*,' with 45.8% saying they were to some extent evening active and 31.7% saying they were pronounced evening active.

Correlations

In looking at correlations between various variables in this research study, the data was taken from the responses to the instrument surveys and fed into the SPSS software. I ran a *Pearson Correlation Coefficient* analysis of multiple variables to determine whether there were any correlations and if so, whether those correlations could be classed as statistically significant and to what degree.

For each of the correlations, the Pearson '*r'* value shows the coefficient correlation between the variables in question. When the '*r*' value is close to 1, this indicates that there is a strong relationship between the two variables in question. What this means is that any changes in one variable will result in significant changes in the other variable.

When the '*r*' value is closer to zero, this is indicative of a weaker relationship between the two variables being analysed. In such instances, changes in one variable would result in very small changes, if any at all, in the second variable. If the '*r*' coefficient value lies between 0.50 and 1, then it can be said to be a strong correlation. A value between 0.30 and 0.49, can be said to be a medium correlation, whereas a value from .29 and below, can be said to be a small correlation.

Looking at the differences between positive and negative correlations, we can see that if the '*r*' value is a positive value, it means that when one variables increases, the other variable also increases. If the Pearson '*r*' value is negative, it indicates that there is an inverse correlation between the two variables, i.e.- when one variable increases, the other decreases.

Also shown in the Pearson correlations box is the Significance value. This is also known as the '*P*' value. The *P* value is a number between 0 and 1. If the *P* value is less than 5%, that is $P<0.05$, then the correlation coefficient is said to be statistically significant and indicative of strong evidence against the null hypothesis (the opposite of our hypothesis).

In looking at how bedtime (hours) correlates with variables related to circadian rhythm, we can draw inferences from the following table.

Correlations

		Bedtime	Awake feeling sluggish	Awake feeling irritable	Drowsy in daytime?	Trouble staying awake?	School performance suffering
Bedtime	Pearson Correlation	1	-.174	-.212*	.178	.157	-.094
	Sig. (2-tailed)		.058	.020	.052	.087	.307
	N	864	864	864	864	864	864
Awake feeling sluggish	Pearson Correlation	-.174	1	.194*	-.349**	-.376**	.170
	Sig. (2-tailed)	.058		.034	.000	.000	.063
	N	864	864	864	864	864	864
Awake feeling irritable	Pearson Correlation	-.212*	.194*	1	-.385**	-.330**	.191*
	Sig. (2-tailed)	.020	.034		.000	.000	.037
	N	864	864	864	864	864	864
Drowsy in daytime?	Pearson Correlation	.178	-.349**	-.385**	1	.569**	-.497**
	Sig. (2-tailed)	.052	.000	.000		.000	.000
	N	864	864	864	864	864	864
Trouble staying awake?	Pearson Correlation	.157	-.376**	-.330**	.569**	1	-.452**
	Sig. (2-tailed)	.087	.000	.000	.000		.000
	N	864	864	864	864	864	864
School performance suffering	Pearson Correlation	-.094	.170	.191*	-.497**	-.452**	1
	Sig. (2-tailed)	.307	.063	.037	.000	.000	
	N	864	864	864	864	864	864

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

From this table, when we look at how a later bedtime correlates with feeling tired or sluggish the following day, we see a negative correlation ($r = -.174$, $p < .058$), indicating there is a weak relationship between the two variables and from this data, there is no statistically significant correlation between them.

Looking at how a later bedtime correlates with awaking and feeling irritable or angry the following day, we see a negative correlation ($r = -.212$, $p < .020$), indicating the causal relationship between the 2 variables is weak, however we can conclude that there is a statistically significant correlation between the two, indicating that a later bedtime is statistically more likely to result in adolescents awaking from sleep still feeling irritable or angry.

A later bedtime correlates with drowsiness or feeling unrefreshed, we see a positive correlation ($r = .178$, $p < .052$), indicating there is a weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

A later bedtime correlates with having trouble staying awake in school, we see a positive correlation ($r = .157$, $p < .087$), indicating there is a weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

A later bedtime correlates with school performance suffering, we see a negative correlation ($r = -.094$, $p < .307$), indicating there is a weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

We can also see that the only correlation of statistical significance is the relationship between adolescents who go to bed later at night and their awaking the following day, feeling irritable or angry.

Correlations

		Sleep hours	Awake feeling sluggish	Awake feeling irritable	Drowsy in daytime?	Trouble staying awake?	School performance suffering
Sleep hours	Pearson Correlation	1	.141	.247**	-.303**	-.272**	.112
	Sig. (2-tailed)		.125	.007	.001	.003	.222
	N	864	864	864	864	864	864
Awake feeling sluggish	Pearson Correlation	.141	1	.194*	-.349**	-.376**	.170
	Sig. (2-tailed)	.125		.034	.000	.000	.063
	N	864	864	864	864	864	864
Awake feeling irritable	Pearson Correlation	.247**	.194*	1	-.385**	-.330**	.191*
	Sig. (2-tailed)	.007	.034		.000	.000	.037
	N	864	864	864	864	864	864
Drowsy in daytime?	Pearson Correlation	-.303**	-.349**	-.385**	1	.569**	-.497**
	Sig. (2-tailed)	.001	.000	.000		.000	.000
	N	864	864	864	864	864	864
Trouble staying awake?	Pearson Correlation	-.272**	-.376**	-.330**	.569**	1	-.452**
	Sig. (2-tailed)	.003	.000	.000	.000		.000
	N	864	864	864	864	864	864
School performance suffering	Pearson Correlation	.112	.170	.191*	-.497**	-.452**	1
	Sig. (2-tailed)	.222	.063	.037	.000	.000	
	N	864	864	864	864	864	864

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From this table, when we look at how a reduced sleep duration correlates with feeling tired or sluggish the following day, we see a positive correlation ($r = .141$, $p < .125$), indicating there is a weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at how a reduced sleep duration correlates with awaking and feeling irritable or angry the following day, we see a positive correlation ($r = .247$, $p < .007$), indicating the causal relationship between the 2 variables is weak, however we can conclude that there is a statistically extremely high significance in correlation between the two, indicating that reduced sleep duration is statistically extremely likely to result in adolescents awaking from sleep still feeling irritable or angry.

A reduced sleep duration correlates with drowsiness or feeling unrefreshed, we see a negative correlation ($r = -.303$, $p < .001$), indicating the causal relationship between the 2 variables is weak, however we can conclude that there is a statistically extremely high significance in correlation between the two, indicating that reduced sleep duration is statistically extremely likely to result in adolescents awaking from sleep with drowsiness or feeling unrefreshed during the daytime at school.

A reduced sleep duration correlates with having trouble staying awake in school, we see a negative correlation ($r = -.272$, $p < .003$), indicating the causal relationship between the 2 variables is weak, however we can conclude that there is a statistically extremely high significance in correlation between the two, indicating that reduced sleep duration is statistically extremely likely to result in an increased frequency of adolescents having trouble staying awake in school, eating meals or engaging in social activity.

A reduced sleep duration correlates with school performance suffering, we see a positive correlation ($r = .112$, $p < .222$), indicating there is a weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

From this data set we can see that there are 3 correlations of statistically extremely high significance in the relationship between adolescents who have reduced sleep duration and their awaking the following day, feeling irritable or angry; or awaking from sleep with drowsiness or feeling unrefreshed during the daytime at school; or having trouble staying awake in school, eating meals or engaging in social activity.

Correlations

		Sleep Latency Score	How often do you delay bedtime?	School performance suffering
Sleep Latency Score	Pearson Correlation	1	.209*	-.111
	Sig. (2-tailed)		.022	.228
	N	864	864	864
How often do you delay bedtime?	Pearson Correlation	.209*	1	-.127
	Sig. (2-tailed)	.022		.167
	N	864	864	864
School performance suffering	Pearson Correlation	-.111	-.127	1
	Sig. (2-tailed)	.228	.167	
	N	864	864	864

*. Correlation is significant at the 0.05 level (2-tailed).

From this table, when we look at how increased Sleep Onset Latency (SOL) correlates with the frequency with which respondents delay their bedtime due to using some form of bedtime technology, we see a positive correlation ($r = .209$, $p < .022$), indicating the relationship between the 2 variables is weak, however we can conclude that there is a statistically significant correlation between the two, indicating that an increase in Sleep Onset Latency (delayed sleep) is statistically more likely to result in adolescents delaying their bedtime due to using some form of bedtime technology or vice versa.

Looking at how increased Sleep Onset Latency correlates with whether respondents feel their school performance suffers as a direct result of sleepiness, we see a negative correlation ($r = -.111$, $p < .228$), indicating there is a weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

From this data set we can see that the only correlation of statistical significance is the relationship between adolescents who delay their bedtime due to using some form of bedtime technology and an increase in their delayed bedtime (Sleep Onset Latency).

Correlations

		How would you rate your sleep	Awake feeling sluggish	Awake feeling irritable	Drowsy in daytime?
How would you rate your sleep	Pearson Correlation	1	-.171	-.357**	.384**
	Sig. (2-tailed)		.062	.000	.000
	N	864	864	864	864
Awake feeling sluggish	Pearson Correlation	-.171	1	.194*	-.349**
	Sig. (2-tailed)	.062		.034	.000
	N	864	864	864	864
Awake feeling irritable	Pearson Correlation	-.357**	.194*	1	-.385**
	Sig. (2-tailed)	.000	.034		.000
	N	864	864	864	864
Drowsy in daytime?	Pearson Correlation	.384**	-.349**	-.385**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	864	864	864	864

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From this table, when we look at how respondents subjectively rated their overall sleep quality and how that correlates with feeling tired or sluggish the following day, we see a negative correlation ($r = -.171$, $p < .062$), indicating there is a weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at how respondents subjectively rated their overall sleep quality correlates with awaking and feeling irritable or angry the following day, we see a negative correlation ($r = -.357$, $p < .000$), indicating that the poorer the rating of sleep quality, the more statistically extremely likely it is to result in adolescents awaking and feeling irritable or angry the following day.

Looking at how respondents subjectively rated their overall sleep quality correlates with drowsiness or feeling unrefreshed, we see a positive correlation ($r = .384$, $p < .000$), indicating a weak causal link between the two variables and a statistically extremely significant likelihood that adolescents will feel drowsy or unrefreshed during the daytime.

From this data set we can see that there are 2 correlations of statistically extremely high significance in the relationship between adolescents who have rated their sleep quality poorly and their awaking the following day, feeling irritable or angry; or awaking from sleep with drowsiness or feeling unrefreshed during the daytime at school.

Correlations

		PSQI score	Where do you put mobile phone?	How often do you delay bedtime?	Do electronic devices affect your sleep?
PSQI score	Pearson Correlation	1	-.047	.091	-.108
	Sig. (2-tailed)		.611	.324	.240
	N	864	864	864	864
Where do you put mobile phone?	Pearson Correlation	-.047	1	-.267**	.162
	Sig. (2-tailed)	.611		.003	.076
	N	864	864	864	864
How often do you delay bedtime?	Pearson Correlation	.091	-.267**	1	-.285**
	Sig. (2-tailed)	.324	.003		.002
	N	864	864	864	864
Do electronic devices affect your sleep?	Pearson Correlation	-.108	.162	-.285**	1
	Sig. (2-tailed)	.240	.076	.002	
	N	864	864	864	864

**. Correlation is significant at the 0.01 level (2-tailed).

From this table, when we look at the relationship between PSQI score and how that correlates with where exactly respondents place their mobile phones when they go to bed, we see a negative correlation ($r = -.047$, $p < .611$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at the relationship between PSQI score and how that correlates with frequency of delaying bedtime due to the use of bedtime technology, we see a positive correlation ($r = .091$, $p < .324$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at the relationship between PSQI score and how that correlates with whether respondents felt that bedtime technology affected their sleep, we see a negative correlation ($r = -.108$, $p < .240$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

This tells us that from this data set, we could draw no statistical inferences between the PSQI score and these three variables.

Correlations

		Improve quality of sleep?	Do electronic devices affect your sleep?	Affected mood?	Affected concentration?	Awake feeling sluggish	Awake feeling irritable	Drowsy in daytime?
Improve quality of sleep?	Pearson Correlation	1	.275**	-.196*	-.123	.142	.230*	-.202*
	Sig. (2-tailed)		.002	.032	.180	.122	.012	.027
	N	864	864	864	864	864	864	864
Do electronic devices affect your sleep?	Pearson Correlation	.275**	1	-.037	-.041	.044	.097	-.179
	Sig. (2-tailed)	.002		.686	.660	.634	.294	.050
	N	864	864	864	864	864	864	864
Affected mood?	Pearson Correlation	-.196*	-.037	1	.537**	-.224*	-.311**	.328**
	Sig. (2-tailed)	.032	.686		.000	.014	.001	.000
	N	864	864	864	864	864	864	864
Affected concentration?	Pearson Correlation	-.123	-.041	.537**	1	-.158	-.282**	.442**
	Sig. (2-tailed)	.180	.660	.000		.085	.002	.000
	N	864	864	864	864	864	864	864
Awake feeling sluggish	Pearson Correlation	.142	.044	-.224*	-.158	1	.194*	-.349**
	Sig. (2-tailed)	.122	.634	.014	.085		.034	.000
	N	864	864	864	864	864	864	864
Awake feeling irritable	Pearson Correlation	.230*	.097	-.311**	-.282**	.194*	1	-.385**
	Sig. (2-tailed)	.012	.294	.001	.002	.034		.000
	N	864	864	864	864	864	864	864
Drowsy in daytime?	Pearson Correlation	-.202*	-.179	.328**	.442**	-.349**	-.385**	1
	Sig. (2-tailed)	.027	.050	.000	.000	.000	.000	
	N	864	864	864	864	864	864	864

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

From this table, when we look at whether the respondents felt they could improve their sleep quality correlates with whether they felt bedtime technology affected their sleep, we see a positive correlation ($r = .275$, $p < .002$), indicating a weak relationship between the two variables and a statistically extremely significant likelihood that adolescents who felt they could improve their sleep quality, also felt that bedtime technology affected their sleep.

Looking at whether the respondents felt they could improve their sleep quality and how this correlates with how quality of sleep affected their mood, energy levels or relationships, we see a negative correlation ($r = -.196$, $p < .032$), indicating the relationship between the 2 variables is extremely weak, however we can conclude that there is a statistically high significance in correlation between the two, indicating that adolescents who felt they could improve their sleep quality, also felt that their quality of sleep affected their mood, energy levels or relationships.

Looking at whether the respondents felt they could improve their sleep quality and how this correlates with how quality of sleep affected their concentration, productivity or ability to stay awake during the day, we see a negative correlation ($r = -.123$, $p < .180$), indicating an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at whether the respondents felt they could improve their sleep quality and how this correlates with awaking from sleep feeling tired or sluggish, we see a positive correlation ($r = .142$, $p < .122$), indicating an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at whether the respondents felt they could improve their sleep quality and how this correlates with awaking from sleep feeling irritable or angry, we see a positive correlation ($r = .230$, $p < .012$), indicating the relationship between the 2 variables is weak, however we can conclude that there is a statistically high significance in correlation between those adolescents who felt they could improve their own sleep quality and those awaking from sleep feeling irritable or angry.

Looking at whether the respondents felt they could improve their sleep quality and how this correlates with how often they felt drowsy or unrefreshed during the daytime, we see a negative correlation ($r = -.202$, $p < .027$), indicating the relationship between the 2 variables is weak. However, we can conclude that there is a statistically high significance in correlation between those adolescents who felt they could improve their own sleep quality and the frequency with which they felt drowsy or unrefreshed during the daytime.

From this data set we can see that there is 1 correlation of statistically extremely high significance in the relationship between whether adolescents felt they could improve their own sleep quality and the feeling that bedtime technology has affected their sleep.

The data set also provides us with 3 correlations of statistically high significance in the relationship between whether adolescents felt they could improve their own sleep quality and those who felt that their quality of sleep affected their mood, energy levels or relationships; or those awaking from sleep feeling irritable or angry; or the frequency with which they felt drowsy or unrefreshed during the daytime.

It also tells us that we could draw no statistical inferences between whether adolescents felt they could improve their own sleep quality and how quality of sleep affected their concentration, productivity or ability to stay awake during the day; or awaking from sleep feeling tired or sluggish.

Correlations

		Awoken by Phone Notifications?	Affected mood?	Affected concentration?	Awake feeling sluggish	Awake feeling irritable	Drowsy in daytime?	Trouble staying awake?
Awoken by Phone Notifications?	Pearson Correlation	1	.186*	.128	-.112	-.268**	.310**	.218*
	Sig. (2-tailed)		.042	.164	.224	.003	.001	.017
	N	864	864	864	864	864	864	864
Affected mood?	Pearson Correlation	.186*	1	.537**	-.224*	-.311**	.328**	.505**
	Sig. (2-tailed)	.042		.000	.014	.001	.000	.000
	N	864	864	864	864	864	864	864
Affected concentration?	Pearson Correlation	.128	.537**	1	-.158	-.282**	.442**	.418**
	Sig. (2-tailed)	.164	.000		.085	.002	.000	.000
	N	864	864	864	864	864	864	864
Awake feeling sluggish	Pearson Correlation	-.112	-.224*	-.158	1	.194*	-.349**	-.376**
	Sig. (2-tailed)	.224	.014	.085		.034	.000	.000
	N	864	864	864	864	864	864	864
Awake feeling irritable	Pearson Correlation	-.268**	-.311**	-.282**	.194*	1	-.385**	-.330**
	Sig. (2-tailed)	.003	.001	.002	.034		.000	.000
	N	864	864	864	864	864	864	864
Drowsy in daytime?	Pearson Correlation	.310**	.328**	.442**	-.349**	-.385**	1	.569**
	Sig. (2-tailed)	.001	.000	.000	.000	.000		.000
	N	864	864	864	864	864	864	864
Trouble staying awake?	Pearson Correlation	.218*	.505**	.418**	-.376**	-.330**	.569**	1
	Sig. (2-tailed)	.017	.000	.000	.000	.000	.000	
	N	864	864	864	864	864	864	864

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

From this table, when we look at the frequency that respondents were awoken by phone notifications and how that correlates with how their quality of sleep affected mood, energy levels or relationships, we see a positive correlation ($r = .186$, $p < .042$), indicating the relationship between the 2 variables is weak, however we can conclude that there is a statistically high significance in correlation between those adolescents who were reported having an increased frequency of troubled sleep because they had been awoken by phone notifications and those who felt a reduction in the quality of sleep was affected their mood, energy levels or relationships.

Looking at how the frequency that respondents were awoken by phone notifications correlates with how quality of sleep affected their concentration, productivity or ability to stay awake, we see a positive correlation ($r = .128$, $p < .164$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at how the frequency that respondents were awoken by phone notifications correlates with whether they awake from sleep feeling tired or sluggish, we see a negative correlation ($r = -.112$, $p < .224$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at how the frequency that respondents were awoken by phone notifications correlates with awaking from sleep feeling irritable or angry, we see a negative correlation ($r = -.268$, $p < .003$), indicating a weak relationship between the two variables and a statistically extremely significant likelihood that those adolescents who were reported having an increased frequency of troubled sleep because they had been awoken by phone notifications and those, also felt they usually awake from sleep still feeling irritable or angry.

Looking at how the frequency that respondents were awoken by phone notifications correlates with how often they feel drowsy or unrefreshed during the daytime, we see a positive correlation ($r = .310$, $p < .001$), indicating a weak relationship between the two variables and a statistically extremely significant likelihood that those adolescents who were reported having an increased frequency of troubled sleep because they had been awoken by phone notifications and those, also reported an increased frequency of feeling drowsy or unrefreshed during the daytime.

Looking at how the frequency that respondents were awoken by phone notifications correlates with how often had trouble staying awake in school, eating meals, or engaging in social activity, we see a positive correlation ($r = .218$, $p < .017$), indicating the relationship between the 2 variables is weak, however we can conclude that there is a statistically high significance in correlation between those adolescents who were reported having an increased frequency of troubled sleep because they had been awoken by phone notifications and those who experienced trouble staying awake in school, eating meals, or engaging in social activity.

From this data set we can see that there are 2 correlations of statistically extremely high significance in the relationship between adolescents who experienced an increased frequency of troubled sleep because they had been awoken by phone notifications and those who felt they usually awake from sleep still feeling irritable or angry; or those who reported an increased frequency of feeling drowsy or unrefreshed during the daytime.

The data set also provides us with 2 correlations of statistically high significance in the relationship between adolescents who experienced an increased frequency of troubled sleep because they had been awoken by phone notifications and those who felt a reduction in the quality of sleep was affecting their mood, energy levels or relationships; or those who experienced trouble staying awake in school, eating meals, or engaging in social activity.

It also tells us that we could draw no statistical inferences between adolescents who experienced an increased frequency of troubled sleep because they had been awoken by phone notifications and those who felt their quality of sleep affected their concentration, productivity or ability to stay awake; or those who awoke from sleep feeling tired or sluggish.

Correlations

		How often do you delay bedtime?	Affected mood?	Affected concentration?	Awake feeling sluggish	Awake feeling irritable	Drowsy in daytime?	Trouble staying awake?
How often do you delay bedtime?	Pearson Correlation	1	.094	.073	-.260**	-.125	.165	.148
	Sig. (2-tailed)		.307	.426	.004	.173	.071	.107
	N	864	864	864	864	864	864	864
Affected mood?	Pearson Correlation	.094	1	.537**	-.224*	-.311**	.328**	.505**
	Sig. (2-tailed)	.307		.000	.014	.001	.000	.000
	N	864	864	864	864	864	864	864
Affected concentration?	Pearson Correlation	.073	.537**	1	-.158	-.282**	.442**	.418**
	Sig. (2-tailed)	.426	.000		.085	.002	.000	.000
	N	864	864	864	864	864	864	864
Awake feeling sluggish	Pearson Correlation	-.260**	-.224*	-.158	1	.194*	-.349**	-.376**
	Sig. (2-tailed)	.004	.014	.085		.034	.000	.000
	N	864	864	864	864	864	864	864
Awake feeling irritable	Pearson Correlation	-.125	-.311**	-.282**	.194*	1	-.385**	-.330**
	Sig. (2-tailed)	.173	.001	.002	.034		.000	.000
	N	864	864	864	864	864	864	864
Drowsy in daytime?	Pearson Correlation	.165	.328**	.442**	-.349**	-.385**	1	.569**
	Sig. (2-tailed)	.071	.000	.000	.000	.000		.000
	N	864	864	864	864	864	864	864
Trouble staying awake?	Pearson Correlation	.148	.505**	.418**	-.376**	-.330**	.569**	1
	Sig. (2-tailed)	.107	.000	.000	.000	.000	.000	
	N	864	864	864	864	864	864	864

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From this table, when we look at the frequency that respondents delay bedtime due to bedtime technology use and how that correlates with how their quality of sleep affected mood, energy levels or relationships, we see a positive correlation ($r = .094$, $p < .307$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at how the frequency that respondents delay bedtime due to bedtime technology use correlates with how quality of sleep affected their concentration, productivity or ability to stay awake, we see a positive correlation ($r = .073$, $p < .426$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at how the frequency that respondents delay bedtime due to bedtime technology use correlates with whether they awake from sleep feeling tired or sluggish, we see a negative correlation ($r = -.260$, $p < .004$), indicating the relationship between the 2 variables is weak, however we can conclude that there is a very high statistical significance in correlation between the frequency that respondents delay bedtime due to bedtime technology use and those who awoke from sleep feeling tired or sluggish.

Looking at how the frequency that respondents delay bedtime due to bedtime technology use correlates with awaking from sleep feeling irritable or angry, we see a negative correlation ($r = -.125$, $p < .173$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at how the frequency that respondents delay bedtime due to bedtime technology use correlates with how often they feel drowsy or unrefreshed during the daytime, we see a positive correlation ($r = .165$, $p < .071$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at how the frequency that respondents delay bedtime due to bedtime technology use correlates with how often had trouble staying awake in school, eating meals, or engaging in social activity, we see a positive correlation ($r = .148$, $p < .107$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

From this data set we can see that there is 1 correlation of very high statistical significance in the relationship between the frequency that adolescents delay their bedtime due to bedtime technology use and those who awoke from sleep feeling tired or sluggish.

It also tells us that we could draw no statistical inferences between the frequency that respondents delay bedtime due to bedtime technology use and how their quality of sleep affected their mood, energy levels or relationships; or those who felt their quality of sleep affected their concentration, productivity or ability to stay awake; or those who awake from sleep feeling irritable or angry; or the frequency that adolescents feel drowsy or unrefreshed during the daytime; or how often adolescents had trouble staying awake in school, eating meals, or engaging in social activity.

Correlations

		Do electronic devices affect your sleep?	Affected mood?	Affected concentration?	Awake feeling sluggish	Awake feeling irritable	Drowsy in daytime?	Trouble staying awake?
Do electronic devices affect your sleep?	Pearson Correlation	1	-.037	-.041	.044	.097	-.179	-.039
	Sig. (2-tailed)		.686	.660	.634	.294	.050	.673
	N	864	864	864	864	864	864	864
Affected mood?	Pearson Correlation	-.037	1	.537**	-.224*	-.311**	.328**	.505**
	Sig. (2-tailed)	.686		.000	.014	.001	.000	.000
	N	864	864	864	864	864	864	864
Affected concentration?	Pearson Correlation	-.041	.537**	1	-.158	-.282**	.442**	.418**
	Sig. (2-tailed)	.660	.000		.085	.002	.000	.000
	N	864	864	864	864	864	864	864
Awake feeling sluggish	Pearson Correlation	.044	-.224*	-.158	1	.194*	-.349**	-.376**
	Sig. (2-tailed)	.634	.014	.085		.034	.000	.000
	N	864	864	864	864	864	864	864
Awake feeling irritable	Pearson Correlation	.097	-.311**	-.282**	.194*	1	-.385**	-.330**
	Sig. (2-tailed)	.294	.001	.002	.034		.000	.000
	N	864	864	864	864	864	864	864
Drowsy in daytime?	Pearson Correlation	-.179	.328**	.442**	-.349**	-.385**	1	.569**
	Sig. (2-tailed)	.050	.000	.000	.000	.000		.000
	N	864	864	864	864	864	864	864
Trouble staying awake?	Pearson Correlation	-.039	.505**	.418**	-.376**	-.330**	.569**	1
	Sig. (2-tailed)	.673	.000	.000	.000	.000	.000	
	N	864	864	864	864	864	864	864

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

From this table, when we look at whether respondents felt that bedtime technology affected their sleep and how that correlates with how their quality of sleep affected mood, energy levels or relationships, we see a negative correlation ($r = -.037$, $p < .686$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at whether respondents felt that bedtime technology affected their sleep correlates with how quality of sleep affected their concentration, productivity or ability to stay awake, we see a negative correlation ($r = -.041$, $p < .660$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at whether respondents felt that bedtime technology affected their sleep correlates with whether they awake from sleep feeling tired or sluggish, we see a positive correlation ($r = .044$, $p < .634$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at whether respondents felt that bedtime technology affected their sleep correlates with awaking from sleep feeling irritable or angry, we see a positive correlation ($r = .097$, $p < .294$), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

Looking at whether respondents felt that bedtime technology affected their sleep correlates with how often they feel drowsy or unrefreshed during the daytime, we see a negative correlation (r = -.179, p < .050), indicating the relationship between the 2 variables is very weak, however we can conclude that there is a statistical significance in correlation between whether respondents felt that bedtime technology affected their sleep and how often they felt drowsy or unrefreshed during the daytime.

Looking at whether respondents felt that bedtime technology affected their sleep correlates with how often had trouble staying awake in school, eating meals, or engaging in social activity, we see a negative correlation (r = -.039, p < .673), indicating there is an extremely weak relationship between the two variables and from this data, it can be said that there is no statistically significant correlation between them.

From this data set we can see that there is 1 correlation of statistical significance in the relationship between whether respondents felt that bedtime technology affected their sleep and how often they felt drowsy or unrefreshed during the daytime.

It also tells us that we could draw no statistical inferences between whether respondents felt that bedtime technology affected their sleep and how their quality of sleep affected mood, energy levels or relationships; or how their quality of sleep affected their concentration, productivity or ability to stay awake; or whether they awake from sleep feeling tired or sluggish; or whether awaking from sleep they feel irritable or angry; or how often they had trouble staying awake in school, eating meals, or engaging in social activity.

The Diurnal Type Scale (DTS), also known as '*chronotype*' or '*circadian typology*' is the manifestation of circadian rhythms in determining whether as person is morning-typed or evening-typed. There are of course the intermediate areas inbetween these two extremes of the scale. Respondents in this study were asked a series of questions derived from Torsvall & Åkerstedt (1980) study questionnaire of the same name. It asks a series of 7 questions and each answer is ranked from 1 to 4. The sum of these answers provides the DTS score, which is indicative of a person's chronotype, between eveningness and morningness.

When performing a Pearson Correlation Coefficient analysis, I noted a positive correlation ($r = .242$, $p < .008$) between the Diurnal Type Scale of adolescents and bedtime, indicating a weak relationship between the two variables and a very high statistically significant likelihood that those adolescents who went to bed later, were more likely to be evening-typed.

There is a negative correlation ($r = -.208$, $p < .023$) between the Diurnal Type Scale of adolescents and where they put their mobile phone during bedtime, indicating a weak relationship between the two variables and a statistically significant likelihood that those adolescents who kept their phone closer to them at night, were more likely to be evening-typed.

There is a negative correlation ($r = .185$, $p < .043$) between the Diurnal Type Scale of adolescents and the frequency that adolescents delay their bedtime due to the use of bedtime technology, indicating a weak relationship between the two variables and a statistically significant likelihood that those adolescents who do delay their bedtime in order to use some form of technology, were more likely to be evening-typed.

From these results we can see that there are 2 correlations of statistical significance in the relationship between the Diurnal Type Scale (DTS) and where they put their mobile phone during bedtime; or the frequency that adolescents delay their bedtime due to the use of bedtime technology.

It also shows a correlation of very high statistical significance in the relationship between the Diurnal Type Scale (DTS) and those adolescents who went to bed at a later time.

There was a negative correlation (r = -.192, p < .036) between adolescents who felt anxious when separated from their mobile phone or other electronic device and the total PSQI score of the adolescents, indicating the relationship between the 2 variables is weak, however we can conclude that there is a statistically high significance in correlation between them.

Correlations

		PSQI score	Do you feel anxious
Do you feel anxious	Pearson Correlation	-.192*	1
	Sig. (2-tailed)	.036	
	N	864	864

*. Correlation is significant at the 0.05 level (2-tailed).

According to the PSQI scale, 60.76% (n= 525) of the adolescents with good sleep quality and 18.4% (n= 159) of adolescents with poor sleep quality, delayed their bedtime due to using some form of technology. From the survey responses, it was clear that 67.5% (n= 583) respondents felt that mobile phones were the form of technology that was most associated with stopping them getting the ideal amount of sleep. The television was the next form of technology that stopped respondents from getting their ideal amount of sleep with 18.3% (n= 158) providing that as a response.

Good or Bad PSQI * How often do you delay bedtime?

		How often do you delay bedtime?			
		Never	Few times each month	Few times each week	Total
Good or Bad PSQI	Good	144	259	266	669
	Poor	36	65	94	195
Total		180	324	360	864

I examined predicators of the PSQI score using stepwise multivariate linear regression analysis with the following independent variables: age, gender, frequency of nocturnal awakening by mobile phone notifications, frequency of staying up too late to use bedtime technology and self-perceived stressfulness of accessibility by mobile phone. My model indicated that frequency of nocturnal awakening by mobile phone notifications was the only variable predictive of a reduced PSQI score (Coefficient = 2.986, $p< .000$, $r^2 = 0.108$, condition index = 2.574).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	2.986	.226		13.199	.000		
	Awoken by Phone Notifications?	.456	.121	.328	3.776	.000	1.000	1.000

a. Dependent Variable: PSQI score

The use of electronic devices stratified by gender is shown in the chart below. Most adolescents delay their bedtime due to some form of technology (78.5%, n= 684). Whilst there was an unequal number of male and female respondents, some clear gender differences emerged, with more boys using delaying their sleep using computers, whereas girls reported higher use of mobile phones.

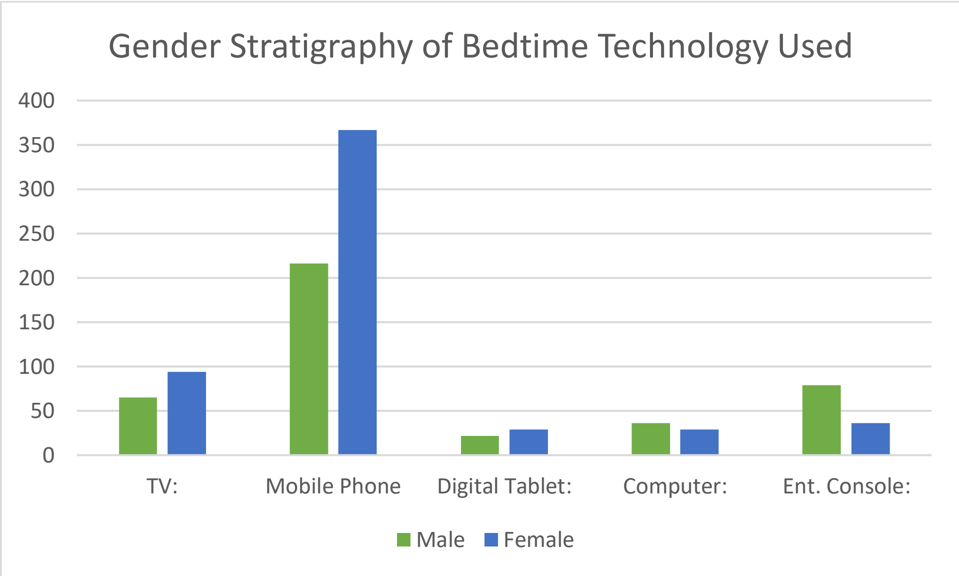


Table of mobile phone proximity when respondents sleep and sleep habit, circadian typology (DTS) and sleep quality (PSQI).

Proximity of mobile phone	Wakeup time	Sleep duration	Sleep quality	DTS	PSQI
In Bed	6.54 ± 0.04 (338)	7.56 ± 0.05 (338)	1.32 ± 0.75 (338)	18.53 ± 2.77 (338)	3.62 ± 1.79 (338)
Far From Bed	6.48 ± 0.32 (346)	7.57 ± 1.27 (346)	1.38 ± 0.84 (346)	18.07 ± 2.38 (346)	3.77 ± 1.85 (346)
Different Room	6.48 ± 0.29 (180)	8.18 ± 1.25 (180)	1.04 ± 0.73 (180)	16.92 ± 3.23 (180)	3.32 ± 1.57 (180)
Total	6.50 ± 0.03 (864)	8.01 ± 0.06 (864)	1.28 ± 0.79 (864)	18.02 ± 2.77 (864)	3.62 ± 1.76 (864)

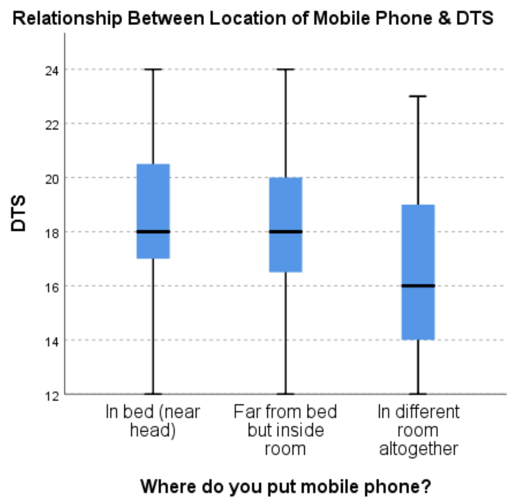
Using the *Kruskal-Wallis test* we can see that adolescents who brought their mobile phones into bed with them were significantly more evening-typed ($z = 5.993$, $df = 2$, $p < 0.050$).

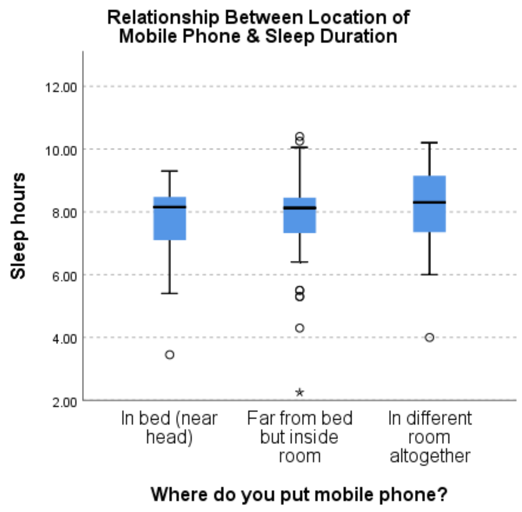
However, the placement of mobile phones during sleep had no significant affects on sleep hours.

Independent-Samples Kruskal-Wallis Test Summary

Total N	864
Test Statistic	5.993[a]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.050

a. The test statistic is adjusted for ties.





Adolescents who were awoken by phone notifications during the night whilst asleep, awoke at 6.55am on average, whereas ones who weren't awoken by phone notifications during the night, awoke at 6.44am on average. This is indicative of the fact that sleep disturbance through phone notifications, resulted in a later waking-up time.

DISCUSSION

From this data set we can see that there is a statistically significant relationship between adolescents who go to bed later at night and their awaking the following day, feeling irritable or angry. This indicates a link between later bedtimes and circadian rhythms. We would have to therefore address the reasons behind these later bedtimes.

There are 3 correlations of extremely high statistical significance in the relationship between adolescents who have reduced sleep duration and their awaking the following day, feeling irritable or angry; or awaking from sleep with drowsiness or feeling unrefreshed during the daytime at school; or having trouble staying awake in school, eating meals or engaging in social activity. This also suggests a link between sleep and circadian rhythms.

There are also 2 correlations of extremely high statistical significance in the relationship between adolescents who have rated their sleep quality poorly and their awaking the following day, feeling irritable or angry; or awaking from sleep with drowsiness or feeling unrefreshed during the daytime at school. Another link between sleep and circadian rhythms!

There is a statistically significant relationship between adolescents who delay their bedtime due to using some form of bedtime technology and an increase in their delayed bedtime (Sleep Onset Latency). This answers our question as to why adolescents may have later bedtimes, due to the use of bedtime technology. This is supported by the further correlation of extremely high statistical significance in the relationship between whether adolescents felt they could improve their own sleep quality and the feeling that bedtime technology has affected their sleep.

The results also show us 3 correlations of statistically high significance in the relationship between whether adolescents felt they could improve their own sleep quality and those who felt that their quality of sleep affected their mood, energy levels or relationships; or those awaking from sleep feeling irritable or angry; or the frequency with which they felt drowsy or unrefreshed during the daytime.

There are 2 correlations of extremely high statistical significance in the relationship between adolescents who experienced an increased frequency of troubled sleep because they had been awoken by phone notifications and those who felt they usually awake from sleep still feeling irritable or angry; or those who reported an increased frequency of feeling drowsy or unrefreshed during the daytime. This shows an affected circadian rhythm and is a natural assumption that punctuated sleep leads to an affected mood the following day.

The data set also provides us with 2 correlations of statistically high significance in the relationship between adolescents who experienced an increased frequency of troubled sleep because they had been awoken by phone notifications and those who felt a reduction in the quality of sleep was affected their mood, energy levels or relationships; or those who experienced trouble staying awake in school, eating meals, or engaging in social activity. Again, this is indicative of troubled sleep which is directly affected by a form of bedtime technology, mobile phones. This also shows a connection between bedtime technology, affected sleep and affected circadian rhythms.

There is 1 correlation of very high statistical significance in the relationship between the frequency that adolescents delay their bedtime due to bedtime technology use and those who awoke from sleep feeling tired or sluggish, providing another link between bedtime technology, sleep and circadian rhythms.

There is also a correlation of statistical significance in the relationship between whether respondents felt that bedtime technology affected their sleep and how often they felt drowsy or unrefreshed during the daytime, showing another causal link.

There is a correlation of statistically high significance between adolescents who felt anxious when separated from their bedtime technology and the total PSQI score of the adolescents. PSQI is a measure of sleep quality.

The majority of adolescents in this study reported delaying their bedtime due to some form of bedtime technology. It's clear that the majority of adolescents felt that mobile phones were the form of bedtime technology that was most associated with stopping them getting the ideal amount of sleep. This is most likely due to their multi-functional nature, combining many different forms of entertainment in one compact and portable unit. The television was the next form of bedtime technology that stopped adolescents from getting their ideal amount of sleep.

There are 2 correlations of statistical significance in the relationship between the Diurnal Type Scale (DTS) and where they put their mobile phone during bedtime; or the frequency that adolescents delay their bedtime due to the use of bedtime technology. It also shows a correlation of very high statistical significance in the relationship between the Diurnal Type Scale (DTS) and those adolescents who went to bed at a later time. These results in themselves are suggestive of a causal link between bedtime technology use on reduced or disturbed sleep and the resulting affected circadian rhythms, typifying adolescents as either morning or evening-typed.

The majority of adolescents in this study, reported that they could sleep for longer. This indicates a very high tendency towards an accumulation of sleep debt over the week. The majority also stated that they felt they could improve their quality of sleep.

The majority had been awoken during their sleep by bedtime technology and just under half of the adolescents said that they felt that electronic devices affected their sleep. The majority also stated that their quality of sleep had affected their mood, energy levels, relationships, their concentration, productivity or ability to stay awake and that they had trouble getting to sleep.

WAYS TO DEAL WITH IT

We know the evidence is clear from previous studies that lack of sleep does indeed have an impact on a person and how they perform during the daytime. We also know that accumulating a sustained sleep deficit is likely to increase the likelihood of health-related issues.

From this research study we can also see that there is statistically clear corroborative evidence that using bedtime technology does have an affect on the body's circadian rhythm, although to what extent is different with each individual person. So we must now turn our attention to ways to resolve this and either reduce the use of bedtime technology to an acceptable level or to remove the harmful effects of the media devices themselves.

Before we address the various reduction strategies, we must first consider the affect on a person's mental health from removing something to which they have become addicted. This is a whole new topic area but I will touch on it briefly here as it's highly relevant.

I'm referring here, as much to adults as I am to adolescents. What happens when you remove, immediately, a source of addiction? To use drug terminology, the individual will go into '*cold turkey*.'

With some addictions, what happens is that the brain experiences an increase in the levels of dopamine and gamma-aminobutyric acid (GABA). Dopamine releases sensations of pleasure and is closely associated with reward and cravings. GABA affects levels of stress in the body and can subdue the body's central nervous system.

Being exposed on a regular basis to anything that can result in an addiction can result in the brain getting used to the feelings experienced and the way the addiction changes neurotransmitters in the brain. The brain can eventually develop a dependency on the addiction and the levels of neurotransmitters that result from it.

So let's just say that a parent, albeit well-meaning, decides to immediately remove the mobile phone from their teenager and not allow them to have it for some period of time. There's a risk that this would lead to a dramatic affect on the adolescent's mental health. Depending on their usual night-time routine, the mobile phone could've played an integral part. Initially, the adolescent could lie in bed for many nights, in a state of anxiety and distress because they have had a source of addiction removed and so abruptly. They will undoubtedly look to replace this with something else. Perhaps, late-night television viewing or playing on the entertainment console. It could even lead to late-night snacking and insomnia. They will also suffer anxiety from not being in contact with their friends and effectively being removed from their social circle. This could dangerously cut the adolescent off from their peer group that they would ordinarily rely upon for moral and emotional support. Taking this further, it could lead to very deep bouts of depression and the negative connotations this can lead to, including self-harming, complete withdrawal from society, rebellious behaviour and suicide.

It is very important that any intervention strategies are delivered in a staged and controlled manner and not in any way that would cause undue distress to the individual.

The affect of instant and uncontrolled removal of an addiction (mobile phone or television viewing) will also lead to feelings of great resentment and won't make for a harmonious household with parent and child pitched against each other in a spiralling battle of wits and control.

Such is the commonplace use of mobile phones and other devices these days that, if removed, they can almost be classed as a 'gateway drug' leading to the adolescent displacing their addiction by filling the void with something else like cigarette smoking or vaping, to pass the time.

Let's have a look at what commonly happens to an adult who instantly gives up smoking. The cravings will build up and most people will return to their addiction after a very short time.

A report published by the University College of London (UCL) in 2017,[245,246] showed that rates for smokers successfully quitting is on the rise and at the highest in a decade, with 19.8% able to quit in their first 6 months of giving up. The average over the previous decade was a success rate of 15.7%. Stoptober, an independent challenge established in 2012 from

Public Health England, was based on research that if a person is able to stop smoking for 28 days, they are five times more likely to successful quit smoking for good. This shows that it can be done but takes a lot of personal willpower and support.

Another common occurrence is that when smokers give up that habit, it is replaced with something else immediately, like eating. Many former smokers tend to put on weight immediately after giving up smoking. This is due to snacking replacing the smoking addiction.

Let's take this one step further and look at what happens when a person who is a drug addict, addicted to something like heroin or cocaine. It's common knowledge that it's almost impossible to stop that addiction overnight. They go into what's known as cold turkey and all sorts of processes occur within their body, physically, mentally and biochemically.

For alcoholics, it's the same thing and this is the reason why many of them have support groups set up for them to guide and support them when giving up. This need for help can last for many years.

So, now we've looked at the importance of not immediately stopping use of any of the bedtime technology devices and to do so in a measured approach, we can now look at the various strategies for dealing with it.

- **<u>Placing the charging station away from the bed</u>**

A lot of the time, a mobile phone or tablet device is still within reach of the bed when the adolescent goes to sleep. This can increase the temptation to continue to use it and move in the bed to read notifications. An option for dealing with this is to place the charging station for the phone or other device away from the side of the bed. This was suggested in a 2014 study by the Fam Community Health.[247]

- **<u>Clinician/Paediatrician/GP intervention:</u>**

A lot of the burden can be undertaken by properly trained clinicians who may be able to better educate both adolescents and also parents.

Asides from the television, these other electronic devices are relatively new in society and medical opinion takes time to be formed, from clinical studies.

There could be NHS-led national initiatives and campaigns to educate the masses about the affects of bedtime technology.

More focus needs to be placed on children and young people and not primarily parents because it will be the younger age demographic that needs to understand why it’s important to moderate their use of electronic devices during bedtime.

There should ideally be a multi-agency approach between clinicians and schools, perhaps co-ordinated by both the Department for Health & Social Care and the Department for Education. It will take a few years for this information to trickle through to the correct age groups if it’s started from an early age.

- **World Health Organisation (WHO) advice:** The current WHO released advice in January 2019 suggested parents avoid letting children use technology an hour before their bed time. It also recommended that parents should set strict limits on screen time. This advice however, didn't specifically cover the use of bedtime technology and the overall affects on circadian rhythms.

- **The American Academy of Pediatrics (AAP) advice:**

  In 2016, the AAP released new guidance for families about media viewing.[248-250]

  They stated:

  - For children younger than 18 months, avoid use of screen media other than video-chatting. Parents of children 18 to 24 months of age who want to introduce digital media should choose high-quality programming, and watch it with their children to help them understand what they're seeing;
  - For children age 2 to 5 years, limit screen use to 1 hour per day of high-quality programs. Parents should co-view media with children to help them understand what they are seeing and apply it to the world around them;
  - For children age 6 and older, place consistent limits on the time spent using media, and the types of media, and make sure media does not

take the place of adequate sleep, physical activity and other behaviours essential to health;

- Designate media-free times together, such as dinner or driving, as well as media-free locations at home, such as bedrooms;
- Have ongoing communication about online citizenship and safety, including treating others with respect online and offline.

Both the 2016 guidance and the most recent advice issued in 2019, only considers media viewing in general and doesn't focus on using bedtime technology or it's affects on the body. I have nevertheless included it here as overall, it is contextually relevant to the basis of this research study.

- **The Canadian Paediatric Society:** 2 years earlier, in 2017, The Canadian Paediatric Society recommendations also released similar advice to the WHO but focused on duration of screen time. They recommended no screen time for children below the age of 2 years, 1 hour per day for 2 to 5 year olds. They recommended avoidance of screens altogether for an hour before bedtime.[251]

- **The NHS:** An article from April 2019 in The Independent newspaper[252], stated that the UK's 4 chief medical officers have gone further than the WHO advice and recommended that phones be banned during bedtimes and meal times.

In the same article, it cites Professor Andrew Przybylski, from the University of Oxford as saying, "*it represents a missed opportunity*" when speaking about the earlier report issued by the WHO.

Professor Kevin McConway, the Emeritus Professor of Applied Statistics at The Open University reported further in response to the WHO's guidance, in a news article on the NHS's own website.[253] He referred to what he called a, "*surprising feature*" of the WHO advice, adding, "*Under every one of its lists of recommendations, the report explicitly says 'strong recommendations, very low-quality evidence'*." He added: "*It seems a little strange that the public health experts who produced the report should feel able to make 'strong recommendations' on the basis of such weak evidence*."

I asked a NHS General Practitioner in the Bolton area of Greater Manchester about the current situation. The GP asked to remain anonymous, however, they did state that there is not currently nor has their previously been any national or regional surveys that requires the GP to ask a few questions about technology use when they're visited by adolescent patients. Perhaps this could be one method of obtaining further data into the subject for clinical research by an age-based survey popping up on the GP's screen when they open an adolescent's medical record in their surgery.

- **<u>Royal College of Paediatrics & Child Health (RCPCH)</u>**

On 4th January, 2019, the RCPCH issued the UK's first advice on screen time.

They stated that there is insufficient evidence to confirm that the amount of time spent using screens is harmful to the health of children. It did accept, however, that extensive screen time can lead to reductions in other important areas of a child's development, namely: socialising, exercising and sleep.

I would note however, that the RCPCH's advice is not particularly relevant to this research study as it only addresses overall screen time and not the actual times of day that screens are used or their affects on circadian rhythms through various means.

- **School intervention**

As well as advice from medical practitioners, the other people that all children and young people have interaction with several times a week are their teachers.

It's important that advice and guidance is delivered through the national curriculum, perhaps in citizenship lessons or science classes, enabling the children to engage in their own research studies to uncover their own results in project work. This should be delivered ideally, both through the Primary school (key stage 2) and Secondary school (key stage 3) curriculums.

I am aware at the moment that Nuffield is delivering great well-being classes in some UK schools through their 'Swap' programme. Part of this teaches children in as young as primary school settings, all about the various aspects of sleep and even addictions and habit behaviours associated with screen time and their affects on mental health and sleep. Nuffield seem to be taking a far more progressive approach than the NHS and far more than the WHO.

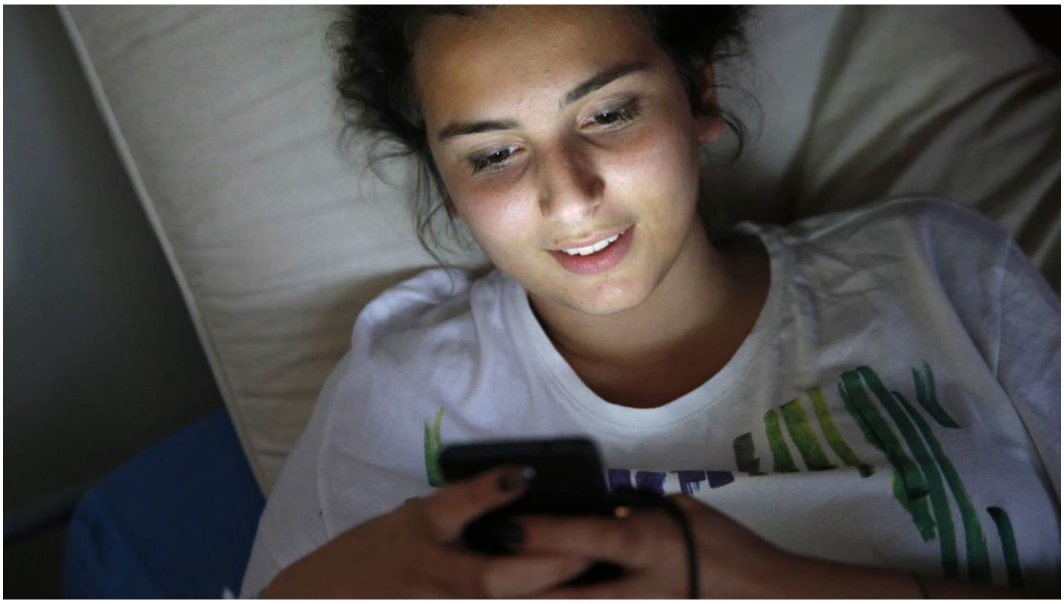
- **Listen to a Podcast Instead of Watching Video on a Mobile Device**

We've already looked at how advances in technology since 2007 have increased the multi-functionality of one small device, a mobile phone. This has meant that it's now become preferable for adolescents to watch video on these smaller screens, instead of watching on the larger screens.

I would suggest also that adolescents prioritise watching YouTube videos over regular television transmissions. Even the streaming services like Netflix, Amazon Prime, Apple TV, Disney TV and BritBox, are all preferred to be watched on a mobile device through convenience.

However, watching something visual through a screen not only exposes the eye to the blue wavelength light but in addition it can stimulate brainwave activity in a way that would delay sleep onset.

Watching video in bed engages the mind, stimulates adrenaline and causes us to think about the viewing content at a time when we should be focusing on dozing off and entering Stage 1 of NREM sleep.



One way around this is to cut out the visual content and instead just listen to a podcast.

This in itself provides engagement of its own for the brain. Therefore it's also important to consider the podcast content. You don't want it to be anything too stimulating or that heightens anxiety. I would even say it's wise to avoid drama podcasts and instead listen to something educational or instructional.

You can search for podcasts via content. There are podcasts that specifically help the listener to get to sleep. You could try downloading and listening to these.

- **<u>Use An Internet Blocker</u>**

A lot of the use of mobile devices in bed is to view YouTube videos and engage in social activity through various social media apps. There are 2 ways you can reduce the information flow closer to bedtimes on these devices.

You can either limit access at the point of connection into the property, i.e.- the WIFI router or, and in cases where adolescents have a sim card with a good data plan in their device, install a blocker app.

When limiting connection through the WIFI router, you can actually filter out devices or the websites they visit, e.g.- YouTube but that wouldn't prevent clever adolescents from accessing through other means, for example, using a proxy server and there's plenty of those websites free to use.

There are several apps that can block access to both mobile apps and also specific websites. They can be used on both mobile devices and computers. Apps like Freedom (<u>https://freedom.to/</u>), AppBlock (<u>https://www.appblock.app/</u>) and RescueTime (<u>https://www.rescuetime.com/</u>). Focusing on the app Freedom, it enables you to select which apps or websites you'd like to block as well as for how long you wish to block them. It works on Windows, Mac, Android, iOS, and Chrome.

- **Use An Auditing App**

Very similar to blocking apps are those that can be used to audit your time spent online. You can use these to monitor overall screen time or to audit your time spent on specific apps or websites.

It's always good to perform an audit in any case on what you're doing on a daily basis. I have read a couple of books on how to improve performance in whatever you're doing and they both suggested performing a 'personal audit.' This is similar to doing a '*Time and Motion Study*.'[254]

Although of greater importance for adults in the workplace than to adolescents still at school, only by establishing how much time you spend on certain activities can you see whether you have any wasted time each day and on which specific activities.

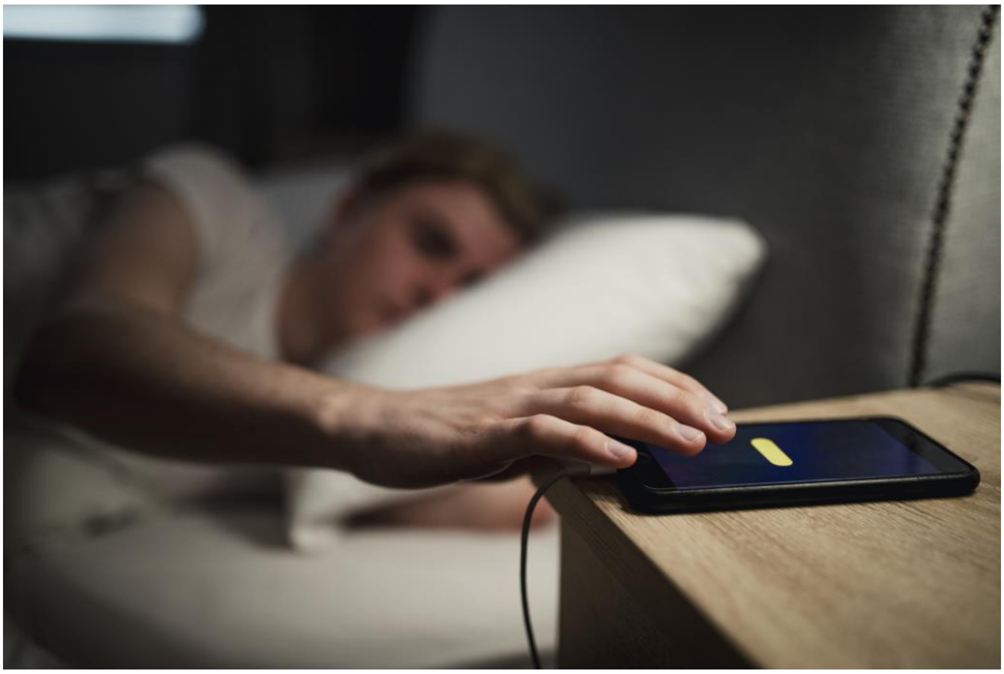
It takes a lot of personal willpower using one of these types of apps because in effect you are shaming yourself by auditing how much time you spend on specific apps each day.

RescueTime (https://www.rescuetime.com/) is a good example of such an app.

- **Put Your Bedtime Technology Out of Reach**

The previous options involve some degree of digital intervention. This one however, requires a lot more personal willpower. It can also rely on helpful intervention from a parent.

However, as we've already seen, you can't just remove such an influence from the bedroom overnight, especially if, as with most people, it forms a solid part of their bedtime/night time routine. Addiction and withdrawal symptoms from mobile devices is as much an issue for adults as it is for children and young people.



This is a real exercise in self-discipline. If you are going to exclude your electronic devices from the bedroom late at night, I would start doing it slowly, in stages. For example, during the first week, place the mobile phone outside the bedroom, perhaps in the kitchen, from 11pm onwards, then the following week, make this 10pm onwards and so on, until an acceptable time has been found for excluding the device from the room. In the second week, you can then slowly remove another electronic device, e.g.- a digital tablet or laptop, if these are being used late into the night. Finally, if you have a television in the bedroom, try to leave the TV controls out of the room after a certain time.

A common theme in most bedrooms across the world these days is the lack of bedside alarm clocks. These have all since been replaced by alarms being set on mobile phones. This is something you will need to consider if removing the mobile phone from the bedroom.

In 2007, AOL released the results of their third annual 'Email Addiction' survey.[255] This indicated that more than 40% of the 4,000 surveyed participants admitted to checking their emails in the middle of the night. This study is 12 years old. This was the year that Apple brought out their 1st generation iPhone with email. Imagine how much more that figure must have now risen due to the prevalence, portability and convenience of mobile devices.

- **Use Night Mode, Screen Filters or Blue Light Blocking Glasses**

If you absolutely must use a mobile phone, tablet or other device in bed at night, there are various solutions available that can be used.

With Apple products like the iPhone and iPad, you can activate night mode, called '*Night Shift*' in the screen settings. This setting actually shifts the on-screen colour that you see from the shorter wavelength blue light to a longer wavelength yellow light. This cuts down on the melatonin-supressing blue light exposure. However, I would advise that until proper clinical research has been conducted into the effectiveness of this night shift function, I would use it with caution.

Another solution would be to use a blue-light filtering app. These react to the time of day and present a screen with the appearance of a more yellow/orange hew in the later hours of the day to reduce the blue light emissions. You might have noticed that some eBook readers like Kindle have for a while now, eliminated the blue light from their spectrum. They have a totally different screen appearance.

For other eBook readers where the screen is not similarly adjusted as with the Kindle, what you can do is reverse the screen settings at night, making the text white and the background black. This reduces blue light emissions.

For those using laptops and computers late into the night, there’s now also software available that can be downloaded and used to reduce the amount of blue light emissions. Such software as *f.lux* which adjusts a display's colour temperature according to location and time of day. Other software is *Redshift*, *SunsetScreen* and *Iris*.

These solutions deal with altering the settings on the device itself but is there something that the viewer themselves can use? And that question brings us to the next solution which is the wearing of blue-light-blocking glasses. According to the American Consumer Reports magazine series (similar to the UK Which reports), the most effective consumer tested model is the Uvex Skyper Blue Light Blocking Computer Glasses.

You can actually wear those same blue-light-blocking glasses around the house or outdoors (if you're brave!) each night and they help to minimise the influence of other light emissions from around the home.

In 2013, a study conducted at Mayo Clinic[256,257] in the U.S.A., concluded with some safety advice stating that if you were unable to avoid looking at a screen late into the night, you should dim the device and keep it at a minimum of 14 inches away from your face. The reason for this is because when people hold devices close to their face and especially in the dark, the light fills the user's visual field entirely so it's important to keep it as a distance.

There is a key issue here in finding a sensible way to balance care for the environment with personal health. The curlicue, compact fluorescent light bulb (CFL) and the increasingly popular LED lights are far more energy-efficient that the older incandescent filament lightbulbs. The problem is, they also emit a greater amount of blue light compared to the old incandescent lightbulbs. Richard Hansler, a light researcher at John Carroll University in Cleveland confirmed in the Harvard Health Publishing,[258] that the older incandescent lightbulbs, whilst still producing some light in the blue spectrum, it is far less than that produced by the modern-day fluorescent lightbulbs.

The lightbulb industry needs to focus efforts towards changing the coatings on the inside of these bulbs to provide a warmer orange emission which features less light in the blue spectrum.

Another recommendation is based on the prevalence of mood lighting now in so many homes. Whilst, blue seems to be a popular setting for night time to make you feel relaxed, it's better to use a red-coloured light and dim the intensity of the light also. The red light is of longer wavelength and has less of an affect on the circadian rhythm and the suppression of melatonin.

- **<u>Creation of '*Tech-Free Zones*' in The Home</u>**

With the National Sleep Foundation recommending a minimum of 30 minutes gadget-free time before bed and having looked at removing these distractive devices from the bedroom, let's take this concept one stage further.

This is more to do with forming a habit or a ritual by getting used to something on a regular basis. In this case, the exclusion of technology from certain areas of the home that would infringe upon family time together.

The easiest way to do this is for the whole family together, to sit down and decide where in the home they would like to designate as tech-free zones. These can be things like the dining room or the kitchen and bedrooms.

Obviously it's probably not a plausible suggestion to designate the living room or lounge as a tech-free zone as most houses would have a television in those rooms. In that case, you can designate those rooms as tech-free zones during certain times of the day.

- **Minimising Exposure to Bright or Blue Light Within One Hour of Bedtime**

We know that blue light imparticular plays a big part if suppressing the production of the sleep hormone melatonin. So it's important to avoid exposure to blue light for an hour before bedtime.

Taking this one step further, whilst blue light has a shorter wavelength and is more likely to suppress melatonin, light in general, of longer wavelengths also does, although to a lesser degree. It's important to remember as well that exposure to light can stimulate the brain at a time when you want to be relaxing for bedtime. For these reasons, it's important to minimise exposure to light an hour before bedtime. Don't forget also that the light emitted from many electronic devices is from the shorter wavelength blue light.

- **Removal of Light Sources From The Bedroom**

It's important to not only exclude mobile devices but also any devices which can act as light sources, either passive or active, from the bedroom.

Even a small plug-in night light can have an affect on the body's circadian rhythm. So it's safer to remove as many of these light sources as possible.

- **Installation of Blackout Blinds in the Bedroom to Block Out Light**

As well as removing light sources in the bedroom, in order to get a good night's sleep and reset the body's circadian rhythm, a sleeper should consider installing either heavy fabric curtains or black out blinds at the window to reduce the amount of light entering the bedroom before, during and at the later stages of bedtime.

- **Read From Paper Hard Copy and Not From a Screen**

Even with night mode or screen filters switched on, reading a book, pdf, report, email, etc. from a Kindle, tablet or other mobile device, it still emits light into the bedroom.

From that perspective, it's a lot safer to read from a paper hard copy using a small bedside lamp to provide enough ambient lighting to read, than to read from a screen with a light source shining directly into your eyes.

- **Switch Off All Notifications**

If you do feel the need, for whatever reason, to continue to sleep with your favourite electronic devices in the bedroom, perhaps the withdrawal anxiety would be too great, then at least ensure that you switch off all sound notifications on all devices. These will constantly wake you up throughout the night and prevent your sleep from cycling through the correct NREM and REM stages.

A good idea would be to just set the '*Do Not Disturb*' function on a schedule so it comes on automatically each night.

As human beings, we have become preconditioned, over the last decade, to react instinctively to any notification by checking the mobile device to see what it is. Just knowing there's a message awaiting your viewing on a phone, is enough to drive you mad until it's read. Hearing these notification sounds throughout the night can lead to episodes of sleep walking to check the phone. It happened to me and I only realised when I looked at my phone the following morning and noticed that I had surprisingly checked my phone during the night and must've accidently taken a photograph of myself, although I had no recollection of actually doing so.

- **Exposure to Bright Light Each Morning**

Once you awake each morning, it is important to get as much light exposure as possible in order to help reset your body's natural circadian rhythm for the day.

You can do this by simply opening the curtains, going out for a walk or sitting in front of one of those bright S.A.D. (Seasonal Affective Disorder) lamps.

By increasing daily morning exposure to bright light, you're helping your body to align itself to the natural hours of the day so that it will be ready to fall asleep and produce melatonin around the night time hours. It's also possible to trigger the morning synthesis of the neurotransmitter *serotonin* in the pineal gland of the brain.[259] Serotonin plays an important role in the promotion of sleep because it is synthesised by the pineal gland to make melatonin.

Interestingly, light exposure has been shown to be one of the best zeitgebers for adjusting the body's circadian rhythm.[178]

- **Avoid Daytime Napping**

If you have managed to accumulate sleep debt during the week, you must try to avoid napping during the daytime. As we have seen from the section on the Sleep Cycle. It is important at the very least, that if you do feel the need for a short nap in the daytime, to set an alarm and ensure that it is only a short nap. You do not want to enter Stage 3 NREM of the sleep cycle which is the deep sleep phase. If you do this, your body will suffer later in that day and your circadian rhythm will be out of balance. A short nap of 30 minutes should be acceptable.

The other drawback of daytime napping is the reduction in daytime light that the body is exposed to which is essential for maintaining a natural circadian rhythm.

- **Development of an Eye Drop Solution to Counter The Harmful Effects of The Blue Light**

There are many eye drop solutions available in the marketplace, both on prescription and others available to buy freely in shops. These range from preventative eye drops, to treatments for pre-existing solutions, to cosmetic eye drops like Optrex '*Eye Dew*.'

There should be research into the development of an eye drop solution that the user can take each morning or evening that filters out the harmful effects of the short wavelength blue light emitted from electronic devices. The treatment can be lasting and protect the eyes all day.

There are currently products on the market that supposedly cater for blue light reduction. However, when you read their ingredients and the instructions, all they do is treat the symptoms of '*ocular blue light strain*' instead of providing any kind of filter solution to actually prevent blue light harm in the first place. So they're more of a solution/treatment, rather than a preventative measure.

- **Keep a Sleep Journal**

Another method to deal with the affects of bedtime technology on your sleep is to keep a sleep journal. This, like many of the other methods, also requires a lot of self-discipline and honesty. Whilst it doesn't, in itself, deal with the issue of using electronic devices around bedtime, it does serve to raise awareness of it and especially how many minutes or hours you're spending using such devices. You should also document your sleep and wake times and how you feel was the quality of your sleep.

- **Forming a Habit/Ritual Around Sleep Times**

One thing that we do know is that if you want to make something happen on a regular basis and you have some degree of control over its occurrence then one of the best ways to go about this is to create a habit or a ritual around it.

By forming a habit around a good sleep routine with consistent sleep and wake times and ensuring bedtime technology influence is kept down to a minimum, you give yourself the best head start in ensuring a strong and healthy circadian rhythm.

You can form this habit by following most of the rituals above in this section and making a few changes to your regular bedtime routine. Don't bring all the changes in at once otherwise it will seem peculiar and your body won't adjust so readily. Instead, let your body adjust to the changes to your routine over a period of 2-3 weeks.

Dr. Maxwell Maltz

So, the next question is, how long will it take to form this habit? The answer is, it's different for each person.

There was a common misconception that

habits can be formed in just 21 days (3 weeks). This came from an observation made by a plastic surgeon called Dr. Maxwell Maltz in the 1950's. This became embedded in the public psyche when it was a commonly held belief with many life coaches and business consultants around the world, e.g.- Tony Robbins.

However, in 2009, Phillippa Lally from the University College, London published a research study[260] in the European Journal of Social Psychology. Her study focused on habit formation amongst 96 subjects over a 12 week period and identified that on average, it took around 66 days for a new behaviour to be formed.

- **Chronotherapy**

The term '*Chronotherapy*'[261] refers to a behavioural therapy treatment where a person's sleep times are systematically delayed or brought forward to an earlier time. It was originally developed to treat people who suffered with delayed sleep onset by gradually delaying their sleep time until their circadian rhythm reached an optimal balance and they slept normally.

Chronotherapy, chronopharmacology and chronobiology are all separate scientific fields. They are all closely tied in with circadian rhythm studies and even studies into the treatment of cancers[262] as well as hypertension (high blood pressure) and asthma.[263,264]

Chronobiological studies[265,266] to identify optimum shift schedule patterns for shift workers have identified that it's more beneficial to rotate shift patterns in a clockwise rotation because shift workers are better able to adjust to those instead of shift times that get increasingly earlier. These chronobiological studies for shift workers use the same treatment methods for people suffering with jet lag and those with Circadian Rhythm Sleep Disorders (CRSD).[267]

- **Understanding of Boundaries in The Home With a Reward/Incentive Mechanism**

One thing that is important is to take this on as a family matter. Something that involves the whole family. If a parent tries to single out a child to get them to solely change their behaviour without engaging or making changes to their own behaviour and routine, then the whole system collapses after a while. It has to be parent-led but with open discussions that involve the whole family so everyone has a say.

This surely is good parenting anyway.

In January 2019, the RCPCH (Royal College of Paediatrics & Child Health) in the UK also provided guidance in this matter.[268] They stated that families should sit down together and discuss the boundaries of screen use in the home. They highlighted the importance that everyone is involved in the discussions and that everyone understands the boundaries and a praise or reward system is put in place for adhering to them.

STUDY STRENGTHS & LIMITATIONS

One of the key limitations of this research study is based in its cross-sectional design. This has provided a representative subset of society, at a specific point in time, leading to cross-sectional data results.

Some variables that haven't been addressed in the study may be associated with the use of late-night bedtime technology and/or circadian rhythms and/or fatigue or optimal cognitive functioning the next day.

In addressing some of these strengths and limitations, I would review the following:

- **Subjective bias in self-completed surveys**

  One of the key limitations of this research study is the subjective nature of the data responses because the survey instrument is self-completed and therefore open to subjective bias.

  I would have preferred to have monitored, objectively, each individual respondent over a month's period and wired them up in a laboratory, taking hourly blood samples, measuring melatonin, cortisol, adrenaline, etc. However, in this research study, this wasn't feasible.

  Self-reported sleep times are also open to miss-reporting where respondents wouldn't necessarily recall, for example, how frequently and to what extent they have delayed sleep onset or even night disturbances, especially if they occur during stage 3 NREM sleep.

A previous study has shown empirically that adolescents have a tendency to over report their overall sleep duration if compared to quantifiable data collated in daily sleep logs or actigraphic information from wearable smart technology.[269]

- **Ambiguous questionnaire response options labels**

Some of the questions I chose to include in the survey instrument for this research study were grouped into different terms on a Likert scale. The use of this type of data research is relatively common in quantitative research.[270] However, it can be seen as a limitation because those terms are, by their very nature, subjective and open to individual interpretation.

For example, in the question section on the Circadian Rhythm, I ask the respondents, 'How would you say your quality of sleep has affected your mood, energy levels or relationships?' The following answers are provided for them to record their response: *Not at all*; *a little*; *Average*, *a lot*, *Heavily affected*.

I think we can all agree these a very subjective terms and what might be 'average' to one person could be considered as 'a lot' for a different respondent. There isn't really any way around this because unless each respondent is given a diary to complete over, say, a month's period, then you can't objectively quantify the answers to this type of question. So it is, in effect, a limitation not just of this study but of this style of questioning.

- **Grouping of ages instead of age as a continuous variable**

In the survey instrument I have required the respondents to provide their ages. However, when it came to statistically analysing the data, I had to group all ages into the one category of 'adolescent.'

However, as we know, this category label covers multiple ages and during adolescence, 1 year, even a few months, can make a large difference behaviourally.

So this grouping could be considered as a limitation to this study and for future research, I might consider analysing the data against the individual ages, thereby showing age as a continuous variable.

- **Academic performance targeting specific demographics**

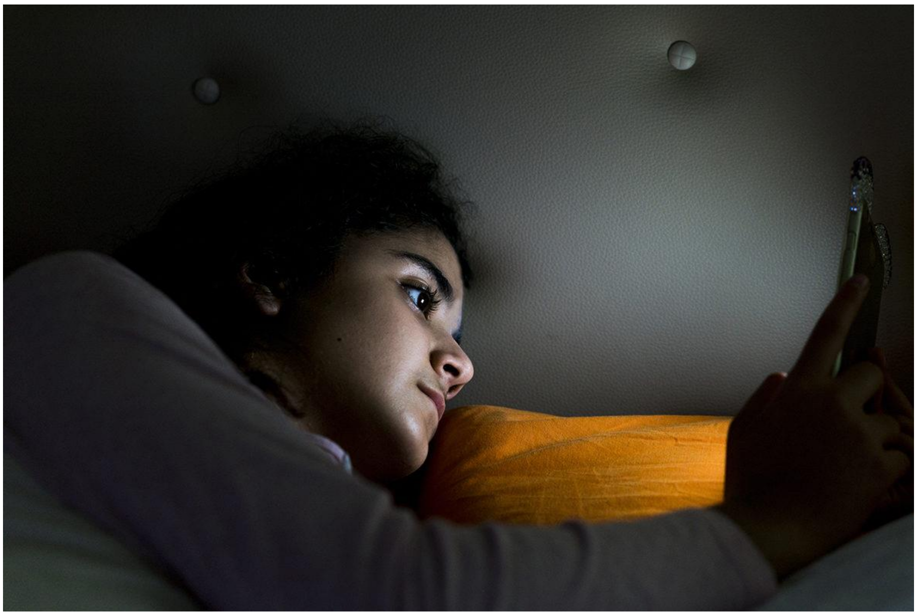
This research study analysed any correlation between late night use of technology and academic performance and behavioural feelings in the school setting. This type of study is only able to assess affects on academic performance in this specific age demographic, i.e.- children and young people, as most adults don't study in an academic setting. The limitation here is that we would have to assume that these research findings are only representative of this specific age demographic and the data can't be of statistical significance or further extrapolated to cover adult age ranges.

- **<u>Grouping of frequency of bedtime technology use & affects on delayed sleep onset, instead of using it as a continuous variable</u>**

Given the brief amount of time available for the respondents to complete the survey instrument, I had to group frequency of use rather than enable the respondent to provide specific hours, daily or a monthly period. This does limit the data but not to the extent that it makes it unusable. The ideal situation, given additional time and to strengthen the findings further, I would suggest allowing the respondents to provide actual numerical values in their responses to provide a continuous variable.

- **<u>Association may not equal causation</u>**

One aspect of this research study is the understanding that whilst there can be an association between the use of bedtime technology and affected circadian rhythms through reduced quality or duration of sleep, that link is not necessarily causal. By that I mean that just because an adolescent uses technology late into the night, this doesn't prove, in all cases, that the reason for the affected circadian rhythm is directly due to the late night use of technology.



In some cases, an adolescent might start to use technology late into the night for other reasons and perhaps even, to help them get to sleep. It may be the case that for some adolescents, they naturally struggle to sleep and for reasons other than using technology late at night, although it's statistically correct to suggest that this is a contributory factor in most cases. It may be that for these few adolescents, their inability to sleep normally leads them to use their phones in bed in order to fill that gap of monotony, instead of lying there and staring up at the ceiling. Perhaps they are using an app, like Headspace or other internet-based sleep interventions, in order to help stimulate certain brainwave activity that will hopefully promote or induce the onset of sleep. These have proven to be an effective solution in treating certain types of sleep disorders[271] and in one protracted study, adolescent use of bedtime technology was seen to be an outcome of sleep disorders and not the main cause.[272]

Another aspect of this limitation is what was referred to in a study by Eggermont (2006)[273] in which he described a situation where reverse causality might occur in which an adolescent whom either requires less sleep or is otherwise having troubled sleep, spends additional time using bedtime technology in order to fill the extra time they have available to them.

In order to examine this further, we would have to look at motivations for using bedtime technology late into the night.

- **<u>Data sample size</u>**

The sample size of 864 in this research study could be seen as both a strength and a limitation. Certainly, the data sample size is large enough to be statistically significant. Respondents also exhibited a mix of socio-economic demographic characteristics. That said, this is currently one of the only pieces of research currently examining the affects of bedtime technology on circadian rhythms in the adolescent age group so as a pioneer in this area, I would prefer to have an even greater data sample size. Sadly, many of the schools didn’t wish to be involved, some not even showing the courtesy to reply to requests.

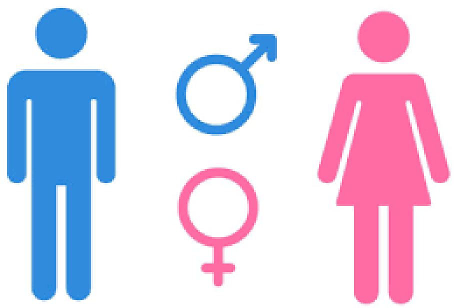
- **<u>Sleep stratigraphy</u>**

For this research study, I considered that a total sleep time of 8 hours was a suitable boundary to categorise the duration of sleep as adequate. The current recommended sleep guidelines for adolescents in the UK from the NHS (as recommended by the Millpond Children's Sleep Clinic)[24] is 9 hours. In adults, inadequate sleep duration is defined as fewer than 7 hours per day.[6,57] On this basis, I've set the 'suitable sleep' boundary as an average, at 8 hours.

Other comparable sleep studies will stratify sleep differently, with some suggesting that less than 9 hours would be classed as a poor and inadequate total sleep time.

- **<u>Gender bias</u>**

Although the largest single data samples obtained came from multi-gender schools, one of the schools that took part in this research study was a single-gender (male) private academic establishment. I don't feel that there is any foundation to claim that gender has a role to play in the use of



bedtime technology or any resultant affects on circadian rhythms. However, for a research study to be considered to be free from as many variables as possible, it would have been better to have had an equal number of male and female gender respondents.

- **Speed of technological advancements**

One of the limitations on conducting research into anything related to technology is the swift advancements in technological changes. As we have seen, just over the last few years, there have been rapid advancements in the compactness, portability and functionality of most screen devices. Certainly the ones which we have addressed in this study as forming part of the definition of 'bedtime technology.'

We have to recognise this and realise that technological advancements may outpace the research into such study areas. It is important, therefore, to stay constantly abreast of new technology and try to adopt an anticipatory approach into research questionnaires.

- **Parental electronic use**

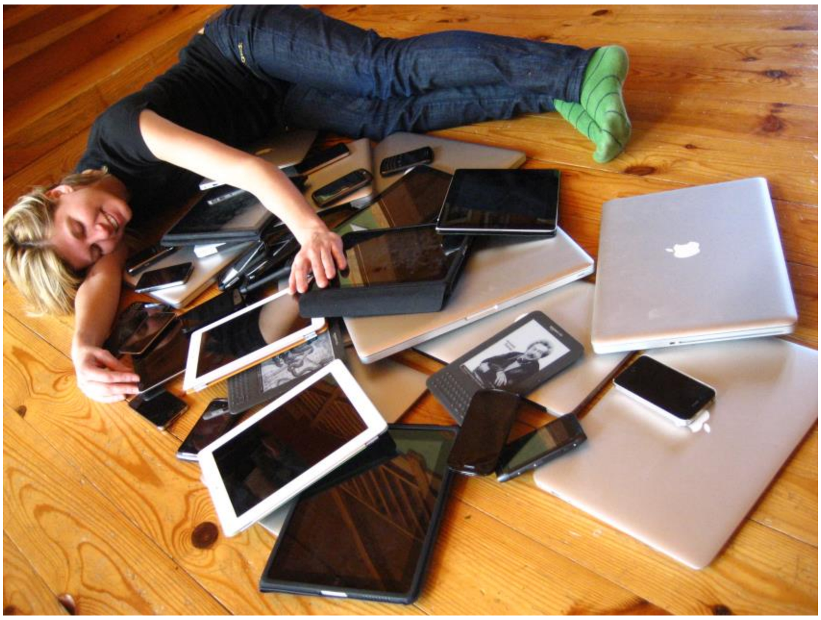
Part of the PSQI questionnaire that was incorporated into my survey instrument did have several questions, in the original, related to a third person's perceptions of the respondent's sleep and moods. This was for parents or roommates to complete. I missed this aspect out as it wasn't feasible for the way in which the survey instruments were delivered in this particular research study. Whilst these few questions dealt with how the parent perceives their child's sleep and moods, it would be of interest in a further study to survey the parents themselves on their own electronic use. I believe this is a limitation of this study in that it's confined purely to the adolescents. Greater data could be obtained by asking either parents themselves or even the adolescent respondents about their own parent's electronic use. As we have seen, a child living in a household is likely to learn behaviour from those closest to them and if parents are also multi-tasking with several screens and late into the night, this could be typified by a similar response in the children within that same household.

SUGGESTIONS FOR FUTURE RESEARCH

I have been happy how this research project has been conducted but if I had longer to conduct the study, there are a few changes that I would wish to make and even some suggestions for anyone else wishing to conduct future research within this field.

- **Multi-tasking of bedtime technology devices**

  Due to the compact nature of modern technology and its ease to bring to bed, technological devices have now found themselves ever closer to us during our bedtime routine.

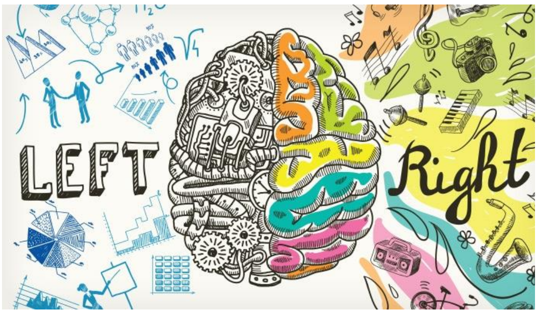


One of the more common themes, especially with adolescents, is the need to multi-task across several devices simultaneously. An example of this would be an adolescent who wishes to communicate with their friends via WhatsApp or text messaging and they use their mobile phone to do this. At the same time, they could have an iPad Mini open so they can watch YouTube videos. In the background, their television or an entertainment gaming console could be playing.

I think it would be an important part of a future study to analyse the effects of the use of multiple screens. Would this lead to an increase in blue light emission and increased melatonin suppression? Would the extra stimuli in the bedroom increase cortisol and adrenaline and increase sleep onset latency?

- **Greater focus on *why* people use media prior to bedtime**

One of the things I looked at in this study was the use of bedtime technology but not specifically at the reasons for the use of the different technology types. This would be something interesting to explore.



Especially in determining why a person would chose to consumer some media content, knowing that they are losing sleep and will feel the ill effects of that when they awake the following day.

Socio-psychological studies have cited a theory called the *Uses and Gratifications Theory* (UGTtheory). This theory states that people deliberately and consciously consume different types of media in order to satisfy specific needs.[274] These needs can range from for example the thirst for knowledge, the need to socially interact, escapism or simple relaxation.[275]

If we can explore the needs in greater detail then perhaps we can address other ways to satiate them instead of allowing the end user to consume media at bedtime.

- **Multifactorial variables**

Most likely, at any given time, there will be multiple factors affecting a person's ability to sleep. These won't always focus solely around the use of bedtime technology.

It's important that we try to understand as many of these different affecters that can trigger episodes of sleeplessness, delayed sleep onset or fatigue.

Taking this idea one step further, future studies could also look at whether any particular affecters, when combined, amplify any sleeping disorders. These could be things like medication use or other comorbid sleep disorders. This study has sought to identify the presence of those in the survey questionnaire. However, when acting together (multifactorial), they can create a very different sleep environment which may be short-lived or of an extended temporal nature.

- **Active-engagement (not just passive) of electronic devices**

Different devices serve different purposes. In their rawest forms, a mobile phone is for communication, whereas a television set or gaming console is purely for entertainment and a Kindle is for reading a book electronically.

The nature and purpose of some of the different devices has led to a situation where some devices require more active engagement than others.

A television, for example, just requires the viewer to watch it from a distance. There's no engagement at all. This led to the nickname of '*the idiot's lantern*,' assuming humans to be like flies around a flickering lantern. This requires *passive* engagement. Other devices are completely the opposite, for example, the mobile phone. This would require active engagement when communicating socially with a peer group late into the night. It is these *active* engagement devices that have been known to have the most negative impact on sleep.[276]

A useful inclusion for future studies would be to assess the use of the different types of devices in a given time period and the hormone secretions related to each different device.

CONCLUSIONS

This study focused on adolescents with my hypothesis being that using bedtime technology at night adversely affects their circadian rhythm.

The research shows that adolescents who use bedtime technology, especially mobile phones, late into the night, has consequences on overall sleep quality. We've been able to demonstrate that the use of bedtime technology results in a reduction in sleep duration, altered sleep patterns, increased frequency of sleep disturbances and delayed sleep onset.

This research study has also shown that there is a strong relationship between the use of bedtime technology, daytime inattention and somnolence. Along with this, the results show a causal link between the use of bedtime technology and an increase in daytime drowsiness, irritability, anxiety and lethargy.

The theory and previous research studies indicate that sleep is negatively affected by both blue light emissions from bedtime technology with screens and the psychophysiological arousal from viewed content. Whilst this research study has been unable to scientifically prove this, it has been able to demonstrate a significant relationship between bedtime technology with screens and affected sleep and circadian rhythms.

Based on the empirical evidence in this study, I find that there is a definite and significant relationship between the late night use of bedtime technology and the many effects it results in on the circadian rhythms of adolescents. On that basis, my hypothesis is proven.

The next step is to find ways to deal with this and better educate both adolescents and parents about not only the harmful affects of bedtime technology but also the potentially harmful effects of completely removing bedtime technology from adolescents with an unmeasured approach.

The overall scope of this research study suggests that there is a public health issue arising here and that intervention and prevention strategies are required. Intervention strategies should always seek to involve parents, the education system, the health service ….and of course, the adolescents themselves.

GLOSSARY OF TERMS

Term:	**Definition:**
AAP	The American Academy of Pediatrics. It's an American professional association of paediatricians, dedicated to the health of children.
ACC	Anterior Cingulate Cortex - the frontal part of the cingulate cortex, a region of the brain. It is implicated in several complex cognitive functions, including empathy, emotion, impulse control and decision-making abilities.
Actigraphic	A non-invasive way to monitor human rest and activity cycles, often through body-worn technology containing an actimetry sensor.
Addiction	A brain condition characterised by the compulsive engagement in rewarding stimuli, often with harmful consequences.
Adrenal burnout	Sometimes called 'adrenal fatigue.' Occurs when the adrenal gland produces excessive amounts of hormones. Often results in sleep disorders and other physiological conditions.
Adrenal cortex	Located on the outside of the adrenal gland. The adrenal cortex brings about the stress response.
Adrenaline	Also known as epinephrine. It is a hormone produced in both the adrenal gland and a small number of neurons in the medulla oblongata in the brainstem. Adrenaline is key to certain bodily functions.
Adrenocorticotropic Hormone (ACTH)	A polypeptide tropic hormone produced in the anterior pituitary gland. ACTH also stimulates the release of the hormone cortisol.
Age-related Macular Degeneration (AMD)	An eye disease that may become progressively worse over time. It's the leading cause of severe, permanent vision loss in people over the age of 60. It occurs when the small central portion of the retina, called the macula, wears down. It has been shown that blue light can cause damage to photoreceptor retinal cells, possibly leading to AMD and impaired vision in later life.

Aldosterone	A hormone that plays an important role in regulating blood pressure by acting upon kidney functions and the colon.
Arrestin	A protein that works to keep the melanopsin sensitive to incoming light.
Asynchronisation	Out of synchronisation.
Attention Deficit Hyperactivity Disorders (ADHD)	A group of behavioural symptoms that include inattentiveness, hyperactivity and impulsiveness.
Attention economy	A description of how there's so much information available in the world, it's sometimes difficult to cut through all the information whilst maintaining a normal degree of attention.
Bedtime technology	Many different types of electronic devices that can be used late into the night.
Biochemistry	The chemical processes occurring within and relating to living organisms.
Bergen Insomnia Scale (BIS)	A scale for measuring insomnia. There are six questionnaire items, of which the first three pertain to sleep onset, maintenance, and early morning wakening insomnia, respectively. The last three items refer to not feeling adequately rested, experiencing daytime impairment, and being dissatisfied with current sleep.
Blue light	A colour in the visible light spectrum that can be seen by human eyes. Blue light is a short wavelength, which means it produces higher amounts of energy. Many modern-day electronic media screens have blue light emissions.
The Canadian Paediatric Society	A Canadian association of paediatricians, committed to working together to advance the health of children and youth by nurturing excellence in health care, advocacy, education and research.
Compact Fluorescent Light bulb (CFL)	A fluorescent lamp designed to replace incandescent light bulbs. The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb. They are far more energy-efficient that the older incandescent filament lightbulbs.

Chronic	Something that is persisting for a long time or constantly recurring.
Chronobiology	A field of biology that examines periodic phenomena in living organisms and their adaptation to both solar and lunar-related rhythms, known as biological rhythms. One such biological rhythm is our circadian rhythm.
Chronopharmacology	The study of the effects of biological rhythms on drugs.
Chronotherapy	A behavioural therapy treatment where a person's sleep times are systematically delayed or brought forward to an earlier time. It was originally developed to treat people who suffered with delayed sleep onset by gradually delaying their sleep time until their circadian rhythm reached an optimal balance and they slept normally.
Chronotype	Describes whether a person is a morning person or a night owl. It is possible that our own chronotypes are influenced genetically and passed down from our ancestors.
Circadian rhythm	Our body's internal body clock. It's the very reason why we fall asleep each night and awake in the mornings and why our bodies will generally feel tired or sleep around the same time each day, when averaged out over a long period. Our circadian rhythm doesn't just exert control over our sleeping patterns, they also cause changes in our behaviour, control our levels of alertness, thermoregulation in the body and hormone production.
Circadian Rhythm Sleep Disorders (CRSD)	These are sleeping disorders typified by insomnia, excessive daytime somnolence, or both. The treatment of CRSD depends very much on the cause which must first be identified. It does typically resolve itself when the circadian rhythm realigns itself with the natural light/darkness cycle.
Clinical Research	This is a branch of research that develops new treatments and furthers knowledge in a specific field within healthcare. The research involves human subjects.
Cognitive functioning	A catchall term used to define the brain's ability to function in areas involving for example, mental reasoning, problem solving, decision making, memory

	recall, comprehension, judgement and attentiveness.
Cold turkey	The cessation of a substance that a person has become dependent upon. These are the unpleasant symptoms of that sudden withdrawal from that substance.
Comorbid sleep disorders	Sleep disorders existing simultaneously with and usually independently of another condition.
Cones	Photoreceptor cells in the retina of the eye. They react to different wavelengths of light and function better to brighter light, as opposed to rods which respond better in dim light. They perceive the colour spectrum for us.
Corticotropin Releasing Hormone (CRH)	CRH is a peptide hormone involved in stress responses. A release of CRH stimulates the synthesis of ACTH from the pituitary gland, which then triggers a response in the adrenal cortex. This is a very essential mechanism in the regular functioning of the body.
Cortisol	Cortisol is known as the 'stress hormone.' It's produced in the adrenal gland and partly responsible for waking us up each morning.
CREST	CREST is the British Science Association's scheme for STEM project work that inspires young people to think and behave like scientists and engineers.
Cronbach's alpha	Cronbach's alpha is a statistical model that is used as a measure of internal consistency, to see how closely related a set of items are as a group.
Cross-functional	Relates to the multi-functional use or purpose of a device and how they can be used for several different things.
Cryptochrome	A pigment found in ganglion cells. They are particularly sensitive to blue light and involved in circadian rhythms.
Data sample	A set of data that has been collected.
Daytime attentiveness	A person's ability to remain attentive and pay close attention during the daytime.
Daytime dysfunction	A person's inability to function either physically or mentally, to their normal level of functioning, during the

	daytime.
Daytime inattentiveness	A person’s inability to remain attentive and pay close attention during the daytime.
Deep sleep phase	This is Stage 3 of NREM sleep, also known as the ‘slow wave sleep’ phase. It’s the sleep stage where all memories from the day are consolidated and processed. It’s the restorative deep sleep phase that helps regeneration and recuperation of the body and the cognitive processes.
Delayed sleep onset	A gradually delayed sleep time.
Delta waves	A change in brain waves as they slow down and increase in amplitude during Stage 3 of NREM sleep (deep sleep phase).
Department for Education	A UK government department, responsible for child protection, education, apprenticeships and wider skills in England.
Department for Health & Social Care	A UK government department, responsible for government policy on health and adult social care matters in England.
Digital native	A person who has been brought up during the age of digital technology and very familiar with computers and other electronic media.
Displacement	When something has moved from its previous position.
Diurnal	Related to the time period of a day.
Diurnal Type Scale	A Likert-type scale constructed by Torsvall & Åkerstedt in 1980, for the purpose of establishing whether survey respondents had a morning or evening disposition.
DLPFC	Dorsolateral Prefrontal Cortex - an area in the prefrontal cortex of the brain. Involved in cognitive control and emotions.
Dopamine	Both a hormone and a neurotransmitter that’s used in circadian rhythms. In popular culture, dopamine is seen as the main chemical of pleasure, cravings and desire and often associated in the media with consumption of chocolate.

EEG	Stands for 'electroencephalogram.' It's a test used to monitor electrical activity in the brain.
Electronic media	All media that uses electronics for the end user to access the content.
Et al.	A scholarly abbreviation of the Latin phrase *et alia*, which means, '*and others*.'
Extremely Low Frequency (ELF)	ELF is electromagnetic radiation with frequencies from 3 to 30 Hz, and corresponding wavelengths of 100,000 to 10,000 kilometres.
Epidemiological studies	The study of diseases in populations of humans or other animals, specifically how, when and where they occur.
Epinephrine	Another name for adrenaline.
eReader	An electronic reading device, for example, a Kindle.
Eveningness	An individual's preference for alertness in the evening and night-times.
Evening typed	Another name for eveningness.
Fight-or-flight response	This is a physiological reaction that occurs in response to a perceived harmful event. The adrenaline is released to make your body respond a lot quicker to the situation. This is when an adrenaline rush occurs.
Ganglion cells	Neurons in the retina. They help convey information from other retinal neurons to the rest of the brain.
Gateway drug	A drug which supposedly leads the user on to more addictive or dangerous drugs.
GMV	Grey Matter Volume. Grey matter areas of the brain contain most of the brain's neural cells. These regions are involved in muscle control, sensory perception and decision-making. The density of cells (volume) in a particular region of the brain appears to correlate positively with various abilities and skills. For example, in this research study I have looked at positive correlations between GMV, sleep and academic performance.

Habitual	Something done constantly or as a habit.
Helsinki Declaration	The World Medical Association (WMA) developed the Declaration of Helsinki in 1964, as a statement of ethical principles for medical research involving human subjects, including research on identifiable human material and data.
Hippocampus	A complex brain structure embedded deep in the temporal lobe of each cerebral cortex. It is an important part of the limbic system, a cortical region that regulates motivation, emotion, learning, and memory.
Homogeneous	An adjective denoting that something is the same throughout.
Human Growth Hormone (HGH)	A peptide hormone that stimulates growth, cell reproduction, and cell regeneration in humans and other animals.
Hypertension	High blood pressure.
Hypothalamus	A small region of the brain, located at the base, near the pituitary gland. The hypothalamus plays a crucial role in many important functions.
Hypnic jerks	A brief and sudden involuntary contraction of body muscles occurring when a person is beginning to fall asleep, often causing the person to jump and awaken suddenly for a moment.
Infradian	Long-term body rhythms lasting longer than 24 hours in duration.
Insomnia	A sleep disorder where people have extreme difficulty in getting to sleep or staying asleep for long enough to feel refreshed the next morning.
Intrinsically photosensitive retinal ganglion cells (ipRGCs)	Also known as photosensitive retinal ganglion cells, or melanopsin-containing retinal ganglion cells. They are a type of neuron in the retina of the eye. They respond to light in the absence of all rod and cone photoreceptors.
IRAS	Integrated Research Application System. It's a single system for applying for the permissions and approvals for health and social care / community care research in the UK.

K complexes	Waveforms that may be seen on an electroencephalogram (EEG). They occur during stage 2 of NREM sleep. They are a mechanism by which the brain protects itself from sudden awakening.
Kruskal-Wallis test	Sometimes also referred to as the '*one-way ANOVA on ranks test*', is a rank-based nonparametric test that can be used to determine if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable.
L.E.D.	Light emitting diode.
Likert-type scale	A linear rating scale found on survey forms, that measures how people feel about something.
Luminosity	An absolute measure of radiated electromagnetic power (light).
Lux	A unit of illuminance, measuring luminous flux per unit area. It is equal to one lumen per square metre.
Medial PFC	Medial Prefrontal Cortex, a region of the brain. Most of the medial frontal cortex is involved in attention.
Medulla oblongata	A long stem-like structure which makes up part of the brainstem.
Melanopsin	A photopigment protein, found primarily in the intrinsically photosensitive retinal ganglion cells (ipRGCs) of the retina at the back of our eyes. The melanopsin in these cells helps them to process levels of ambient light and relay this as signals to aid the circadian rhythm in the body.
Melatonin	A hormone that plays a very important role in the body's circadian rhythm cycle. It is produced in the pineal gland in the brain and synthesised in response to stimulus from light and darkness.
Monochromatic	A light of a single wavelength or frequency. Monochromatic colours are all the colours of a single hue.
Morningness	An individual's preference for alertness in the morning,

	as opposed to eveningness where they are prone to be more alert in the evenings.
Morning typed	Another name for morningness.
Morphometry	The quantitative analysis of matter, encompassing size and shape.
MRC	The Medical Research Council. Responsible for co-coordinating and funding medical research in the United Kingdom.
MRI	Magnetic resonance imaging (MRI) is a type of scan that uses strong magnetic fields and radio waves to produce detailed images of the inside of the body.
NASA	The National Aeronautics and Space Administration.
National Sleep Foundation	A US-based organisation created to promote public understanding of sleep and sleep disorders. It seeks to improve public health and safety by supporting sleep-related education, research, and advocacy.
Neuron	A cell that carries electrical impulses. Neurons are the basic units of our nervous system.
Neuropeptides	Small protein-like molecules used by neurons to aid the flow of communication between one another.
Neurophysiology	A branch of physiology and neuroscience that is concerned with the study of the functioning of the nervous system.
Neuroscientist	A scientist who has specialised knowledge in the field of neuroscience, the branch of biology that deals with the physiology, biochemistry, anatomy and molecular biology of neurons and especially their association with behaviour and learning.
Neurotoxins	Toxins that are destructive to nerve tissue.
Neurotransmitter	A type of chemical messenger which transmits signals across a chemical synapse from one neuron (nerve cell) to another neuron, muscle cell, or gland cell.
NHS	The National Health Service (NHS). Established in the U.K. in 1948 as one of the major social reforms since the

	Second World War. The founding principles were that services should be comprehensive, universal and free at the point of delivery.
Night Shift	A screen setting on iPhones and iPads that shifts the on-screen colour that you see from the shorter wavelength blue light to a longer wavelength yellow light. This cuts down on the melatonin-supressing blue light exposure.
Night terrors	Episodes of screaming, intense fear and flailing while still asleep.
NREM sleep	Non-rapid eye movement sleep, consisting of sleep stages 1–3. There are distinct characteristics in each individual sleep stage.
Objective	Independent from individual subjectivity caused by perception, emotions, personal feelings or opinions or imagination. Something that is factually accurate.
Oestrogen	The primary female sex hormone. Responsible for the development and regulation of the female reproductive system and secondary sex characteristics.
Opsin	A protein which forms part of the visual pigment rhodopsin and is released by the action of light.
Pavlov's Dog	Classical conditioning, originally undertaken in experiments using dogs by the Russian physiologist Ivan Pavlov during the 1890s when researching salivation in dogs in response to being fed.
Pearson's Correlation Coefficient	Also referred to as Pearson's *r*, the Pearson product-moment correlation coefficient or the bivariate correlation, is a measure of the linear correlation between two variables. In other words, the strength of the association between two given variables.
Period gene	A section of DNA which has an affect on circadian rhythms and determines the period length of circadian and ultradian rhythms.
Phase Response Curve (PRC)	The curve describing the relationship between light exposure (the stimulus) and a shift in the circadian rhythm (the response).
Photopic lux	Describes an average response of the colour vision

	receptors (cones). A candle at 1 meter distance gives 1 photopic lux of light. Typical room illumination is in the order of 300-500 lux, whereas outdoor light varies from 1500 lux on a cloudy day to 100000 lux on a sunny day.
Photoreception	The mechanisms of light detection that lead to vision and depends on specialised light-sensitive cells called photoreceptors, which are located in the eye.
Pilot test	A small scale preliminary test conducted in order to evaluate feasibility, duration, ensure face validity and improve upon the study design prior to launching the full-scale research project.
Pituitary gland	A small gland that plays a major role in regulating vital body functions and general wellbeing. It controls the activity of most other hormone-secreting glands.
Polysomnography (PSG)	A sleep study, used to diagnose sleep disorders. It records brain waves, the oxygen level in blood, heart rate and breathing, as well as eye and leg movements.
Precuneus	A brain region on the medial surface of each brain hemisphere, involved in a variety of complex functions. It is located in front of the cuneus (the upper portion of the occipital lobe).
Prefrontal cortex	A region of the brain that has been implicated in complex cognitive behaviour, personality, decision making, and moderation of social behaviour.
Progesterone	A hormone released by the corpus luteum in the ovary. It plays important roles in the menstrual cycle and in maintaining the early stages of pregnancy.
PSQI	Pittsburgh Sleep Quality Index. A self-reported questionnaire that assesses sleep quality over a 1-month time period. The measure consists of 19 individual items, creating 7 components that produce one global PSQI score.
Psychophysiological arousal	Something that stimulates our physiological, emotional or mental states.
Quantitative analysis	Analysis of quantifiable information by means of complex mathematical and statistical modelling.

Qualitative analysis	Subjective analysis based on non-quantifiable information.
RCPCH	Royal College of Paediatrics & Child Health, the professional body for paediatricians in the United Kingdom.
REC	NHS Research Ethics Committee. They review research applications and give an opinion about whether the research is ethical. There are more than 80 NHS Research Ethics Committees across the UK. They exist to safeguard the rights, safety, dignity and well-being of research participants.
REM sleep	Rapid eye movement sleep. The 4^{th} stage of sleep. It's a unique phase of sleep, distinguishable by random/rapid movement of the eyes.
Reactive oxygen species	A type of unstable molecule that contains oxygen and that easily reacts with other molecules in a cell. A build-up of reactive oxygen species in cells may cause damage to DNA, RNA, and proteins.
Respondent	A person who replies to something, especially one supplying information for a questionnaire.
Retina	A thin layer of tissue that lines the back of the eye on the inside. It is located near the optic nerve. The purpose of the retina is to receive light that the lens has focused, convert the light into neural signals, and send these signals on to the brain for visual recognition.
Rhodopsin	Pigment found in the rods of the retina. Extremely sensitive to light and enables vision in low-light conditions.
Rods	Photoreceptor cells in the retina of the eye. They react to different wavelengths of light and function better in less intense light, as opposed to cones which respond better in more intense light. They are used in our peripheral vision.
S.A.D. (Seasonal Affective Disorder)	A type of depression that recurs on a seasonal basis. It is most likely triggered by the lack of sunlight in winter, which affects levels of hormones.
Serotonin	A neurotransmitter produced in the pineal gland of the

	brain. Serotonin plays an important role in the promotion of sleep because it is synthesised by the pineal gland to make melatonin.
Sleep apnoea	A serious condition where the muscles in the throat relax during sleep causing the sufferer to temporarily stop breathing whilst they sleep.
Sleep Cycle	Whilst we sleep our heart rate and body temperature decrease and our brains undergo significant changes in brain wave activity. This produces the varying stages of sleep that our bodies undergo on a daily basis. It's a cyclical event. To have peaceful and undisturbed sleep, a sleeper must go through the four stages of the sleep cycle and generally complete several sleep cycles per period of sleep. These four stages are split into Non-REM (NREM) sleep and REM sleep.
Sleep debt	The cumulative effect of not getting enough sleep in a given time period. A large accumulation of sleep debt may lead to mental or physical fatigue.
Sleep deficit	Another term for 'sleep debt.'
Sleep displacement	When sleep is displaced to a later time due to other activities or distractions occurring. As a result of the absence of time boundaries when using electronic media around bedtime, it is more likely to lead to time displacement.
Sleep environment	The area where a person sleeps. It includes not just physical aspects like the bedding but also things like room temperature, air flow, etc.
Sleep inertia	Where a person feels very sluggish for the rest of the day, especially after a person has been awoken during their REM stage of the sleep cycle.
Sleep latency	Another term for 'Sleep Onset Latency.'
Sleep Onset Latency (SOL)	Also called 'Sleep Latency.' It's the amount of time it takes a person to go from being fully awake to sleeping. It may be compounded by the use of mobile phones, extending waking hours further into the night to enable the furthering use of the mobile phone.
Sleep spindles	Waveforms that may be seen on an

	electroencephalogram (EEG). They occur during stage 2 of NREM sleep. They are a mechanism by which the brain protects itself from sudden awakening.
Sleep stratigraphy	The different layers of sleep in the sleep cycle.
Sleep/wake cycle	Another term for 'sleep cycle.'
Slow wave sleep	Stage 3 NREM sleep. The sleep stage where all memories from the day are consolidated and processed. It's the restorative deep sleep phase that helps regeneration and recuperation of the body and the cognitive processes.
Social jet lag	A temporary disturbance of circadian rhythms as a result of social activities.
Socio-psychological studies	The scientific study of how people's thoughts, feelings, and behaviours are influenced by the actual, imagined or implied presence of others.
Solid-state lighting (SSL)	A bichromatic light created by mixing a blue light LED with a yellow phosphor which has a peak emission around 580 nm. To the naked eye, this bichromatic light appears white in colour.
Somnolence	A state of strong desire for sleep, or sleeping for unusually long periods.
Spectral range	The wavelength range.
Subjective	Something based on or influenced by personal feelings, tastes, or opinions and not scientific facts.
Stepwise Multivariate Linear Regression Analysis	A method of regressing multiple variables while simultaneously removing those that aren't important. Essentially it does multiple regressions a number of times, each time removing the weakest correlated variable. It is used to measure the degree at which multiple independent variables (predictors) and more than one dependent variable (responses), are linearly related.
Suprachiasmatic nucleus (SCN)	A network of smaller oscillators based in the hypothalamus in the brain, that functions as the master controller in the circadian rhythm process.

Synchrony effect	Describes what happens when your circadian rhythm is at its peak and you're feeling very alert. During this state your academic performance will most likely also be at its peak.
Temporal desynchrony	A term I created to describe how the circadian rhythm is out of synchrony through time displacement.
Testosterone	The primary male sex hormone. In male humans, testosterone plays a key role in the development of male reproductive tissues.
Thermoregulation	A process that allows the body to maintain its core internal temperature.
Time and Motion Study	A business efficiency technique assessing what motions or activities are undertaken in given time periods.
Time Shifting	The process where use of bedtime technology displaces sleep to a later bedtime and as a result, a later awake time occurs the following morning.
Total Sleep Time (TST)	The amount of actual sleep time in a sleep period. Equal to the total sleep episode less the awake time.
t - Test	Used to establish if the correlation coefficient is significantly different from zero, and, hence that there is evidence of an association between the two variables. In other words, how statistically significant the association is between the variables.
Ultradian	Body rhythms lasting under 24 hours. Examples are heart beats, respiration and eyes blinking. These are things that a person generally has little conscious control over and they're all vital functions in the body.
Uses and Gratifications Theory (UGTtheory)	This theory states that people deliberately and consciously consume different types of media in order to satisfy specific needs.
VBM	Voxel-Based Morphometry - a scan that provides a comprehensive assessment of anatomical volume differences throughout the brain without bias towards any specific region.
Voxel	A measurement, like a pixel in three-dimensional space.

WHO	World Health Organisation, a specialised agency of the United Nations that is concerned with international public health. It was established in 1948.
Zeitgeber	An external or environmental cue that helps synchronise our circadian rhythms to the natural 24-hour light/dark cycle.
Zeitgeist	The general mood or quality of a particular period of history, as shown by the ideas, beliefs, etc. common at the time.

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APPENDICES

1 Questionnaire

2 NHS Integrated Research Application System (IRAS) online application data responses

3 NHS Medical Research Council (MRC) research application form

4 NHS Research Ethics Council (REC) online application data responses

Today's date:	
Age:	
Gender:	

DIRECTIONS:

This questionnaire was developed by the researcher for the purpose of gathering information related to factors that have been determined to have an affect on sleep and the body's circadian rhythm. The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. This questionnaire is anonymous and you can not be identified by the results you provide. Some of the questions require you to tick a box, others to score yourself on a scale, whereas others just require you to circle either a *Yes* or *No*. Please answer all questions.

SLEEP PATTERN:

What are your usual bedtimes?

	Bedtime	Time taken to fall asleep	Wake-up time	Out of bed time
Weekdays:	________*am/pm*	________*hrs/min*	________*am/pm*	________*am/pm*
Weekends:	________*am/pm*	________*hrs/min*	________*am/pm*	________*am/pm*

Do you consider yourself a night owl? YES / NO

Do you consider yourself a morning person? YES / NO

Do you usually feel that you could sleep for longer? YES / NO

How long does it take you to fall asleep, on average?

[ ] 0 – 15 mins [ ] 16 – 30 mins [ ] 31 – 45 mins

[ ] 46 – 60 mins [ ] > 1 hour

SLEEP QUALITY:

During the last month, how would you rate your sleep quality overall?

[ ] Very good [ ] Fairly good [ ] Fairly bad [ ] Very bad

Do you feel that you could improve the *quality* of your sleep? YES / NO

Do you currently suffer from any of the following sleep disorders? (please select all that apply)

[ ] Insomnia (struggling to get to sleep) [ ] Restless leg syndrome

[ ] Narcolepsy [ ] Sleepwalking

[ ] Sleep/Night terrors [ ] I do not suffer from any sleeping disorders

Have you seen a doctor before about your sleep or a daytime alertness problem? YES / NO

During the last month, how often have you taken medicine to help you sleep?

[ ] Not at all [ ] less than once a week

[ ] Once or twice a week [ ] 3 or more times a week

Do you need an alarm clock, the help of someone else or some other aid to wake you up in the mornings? YES / NO

During the last month, how often have you had trouble sleeping because you.....

		Not during the past month	*Less than once a week*	*Once or twice a week*	*Three or more times a week*
(a)	... can't get to sleep within 30 minutes	[ ]	[ ]	[ ]	[ ]
(b)	... wake up in middle of the night or early morning	[ ]	[ ]	[ ]	[ ]
(c)	... have to get up to use the bathroom	[ ]	[ ]	[ ]	[ ]
(d)	... can't breathe comfortably	[ ]	[ ]	[ ]	[ ]
(e)	... cough or snore loudly	[ ]	[ ]	[ ]	[ ]
(f)	... feel too cold	[ ]	[ ]	[ ]	[ ]
(g)	... feel too hot	[ ]	[ ]	[ ]	[ ]
(h)	... had bad dreams	[ ]	[ ]	[ ]	[ ]
(i)	... have pain	[ ]	[ ]	[ ]	[ ]
(j)	... were awoken by phone notifications	[ ]	[ ]	[ ]	[ ]

SLEEP ENVIRONMENT:

Do you usually share your bedroom with someone else when sleeping? YES / NO

Do you usually go to sleep with music, TV, etc on? YES / NO

Do you usually sleep with a light on in your bedroom? YES / NO

Where do you put your mobile phone when you go to bed?

[ ] In bed (near head) [ ] Far from bed but inside room [ ] In different room altogether

When falling asleep, if you hear your phone notification go off, how do you usually respond?

[ ] Respond very quickly [ ] Respond but slowly

[ ] Check it but don't respond [ ] I just carry on sleeping

TECHNOLOGY:

At what age did you receive your first mobile phone? [_______years old]

How often would you say that you delay your bedtime due to using some form of technology (e.g.- mobile phone, computer, TV, PlayStation, etc.)?

[ ] Never [ ] Few times each month [ ] Few times each week

Do you feel anxious when separated from your mobile phone or tablet? YES / NO

Do you feel you need to be accessible by phone/tablet all day (including the night)? YES / NO

If so, do you find that feeling you have to be accessible by phone all the time is stressful or makes you feel anxious?

[ ] Not at all stressed [ ] Little bit stressful [ ] Rather stressful

[ ] Very stressful [ ] n/a

Have you tried to reduce your use of technology in the bedroom late at night? YES / NO

If so, were you at all successful? YES / NO / n/a

Do you feel that electronic devices (e.g.- mobile phone, computer, TV, Xbox, etc.) affects your sleep in any way? YES / NO

Which technology do you feel is stopping you from getting the ideal amount of sleep that you need to function at your best? (please select as many as you feel are relevant)

[ ] Television [ ] Mobile phone [ ] Digital tablet

[ ] Computer [ ] Entertainment console (Xbox, PlayStation ,etc)

CIRCADIAN RHYTHM:

How would you say your quality of sleep has affected your mood, energy levels or relationships?

[ ] Not at all [ ] A little [ ] Average

[ ] A lot [ ] Heavily affected

How would you say your quality of sleep has affected your concentration, productivity or ability to stay awake?

[ ] Not at all [ ] A little [ ] Average

[ ] A lot [ ] Heavily affected

How often would you say you have trouble getting to sleep?

[ ] Not at all [ ] A little [ ] Average

[ ] A lot

How often would you say you lie awake at night with your mind racing, feeling worried, anxious or depressed?

[ ] Not at all [ ] A little [ ] Average

[ ] A lot

Do you usually awake from sleep still feeling tired or sluggish? YES / NO

Do you usually awake from sleep still feeling irritable or angry? YES / NO

How often do you feel drowsy or unrefreshed during the daytime (including lesson times)?

[ ] Not at all [ ] A little [ ] Average

[ ] A lot

During the last month, how often have you had trouble staying awake in school, eating meals or engaging in social activity?

[ ] Not at all [ ] Less than once a week

[ ] Once or twice a week [ ] 3 or more times a week

Do you feel that your school performance may suffer because of sleepiness? YES / NO

During the last month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

[ ] No problem at all [ ] Only a very slight problem

[ ] Somewhat of a problem [ ] A very big problem

On a normal school day, when would you *prefer* to rise, if you were totally free to arrange your time? [ ] before 06:30 [ ] 06:30-07:29 [ ] 07:30-08:29 [ ] 08:30 or later

On a normal school day, when would you *prefer* to go to bed, if you were totally free to arrange your time? [ ] before 21:00 [ ] 21:00-21:59 [ ] 22:00-22:59 [ ] 23:00 or later

If you *always* had to go to bed at midnight, what do you think it would be like to fall asleep at that time?

[ ] *very difficult* - would lie awake for a long time [ ] *rather difficult* - would lie awake for some time

[ ] *rather easy* - would lie awake for a short time [ ] *easy* - would fall asleep pretty much straight away

If you *always* had to get up at 06:00, what do you think it would be like to get up then?

[ ] very difficult and unpleasant [ ] rather difficult and unpleasant

[ ] a little unpleasant but no great problem [ ] easy - no problem at all

When do you *usually* begin to feel the first signs of tiredness and need for sleep?

[ ] before 21:00 [ ] 21:00-21:59 [ ] 22:00-22:59 [ ] 23:00 or later

How long does it usually take you before you *'come to your senses'* in the morning after waking up from a night's sleep?

[ ] 1 - 10 min [ ] 11 - 20 min [ ] 21 - 40 min [ ] more than 40 min

Please indicate when you are most *'active'* either in the *morning* or in the *evening*.

[ ] pronounced morning active (i.e.- morning alert and evening tired) [ ] to some extent morning active

[ ] to some extent evening active (i.e.- morning tired and evening alert) [ ] pronounced evening active

Welcome to the Integrated Research Application System

IRAS Project Filter

The integrated dataset required for your project will be created from the answers you give to the following questions. The system will generate only those questions and sections which (a) apply to your study type and (b) are required by the bodies reviewing your study. Please ensure you answer all the questions before proceeding with your applications.

Please complete the questions in order. If you change the response to a question, please select 'Save' and review all the questions as your change may have affected subsequent questions.

Please enter a short title for this project (maximum 70 characters)
The Affect of Use of Bedtime Technology on The Body's Circadian Rhythm

1. Is your project research?

(•) Yes ( ) No

2. Select one category from the list below:

( ) Clinical trial of an investigational medicinal product

( ) Clinical investigation or other study of a medical device

( ) Combined trial of an investigational medicinal product and an investigational medical device

( ) Other clinical trial to study a novel intervention or randomised clinical trial to compare interventions in clinical practice

( ) Basic science study involving procedures with human participants

(•) Study administering questionnaires/interviews for quantitative analysis, or using mixed quantitative/qualitative methodology

( ) Study involving qualitative methods only

( ) Study limited to working with human tissue samples (or other human biological samples) and data (specific project only)

( ) Study limited to working with data (specific project only)

( ) Research tissue bank

( ) Research database

If your work does not fit any of these categories, select the option below:

( ) Other study

2a. Please answer the following question(s):

a) Does the study involve the use of any ionising radiation?	( ) Yes	(•) No
b) Will you be taking new human tissue samples (or other human biological samples)?	( ) Yes	(•) No
c) Will you be using existing human tissue samples (or other human biological samples)?	( ) Yes	(•) No

3. In which countries of the UK will the research sites be located? *(Tick all that apply)*

[x] England
[ ] Scotland

☐ Wales
☐ Northern Ireland

3a. In which country of the UK will the lead NHS R&D office be located:

◯ England
◯ Scotland
◯ Wales
◯ Northern Ireland
◉ This study does not involve the NHS

4. Which applications do you require?

☐ NHS/HSC Research and Development offices
☐ Social Care Research Ethics Committee
☐ Research Ethics Committee
☐ Confidentiality Advisory Group (CAG)
☐ Her Majesty's Prison and Probation Service (HMPPS)

5. Will any research sites in this study be NHS organisations?

◯ Yes ◉ No

6. Do you plan to include any participants who are children?

◉ Yes ◯ No

7. Do you plan at any stage of the project to undertake intrusive research involving adults lacking capacity to consent for themselves?

◯ Yes ◉ No

Answer Yes if you plan to recruit living participants aged 16 or over who lack capacity, or to retain them in the study following loss of capacity. Intrusive research means any research with the living requiring consent in law. This includes use of identifiable tissue samples or personal information, except where application is being made to the Confidentiality Advisory Group to set aside the common law duty of confidentiality in England and Wales. Please consult the guidance notes for further information on the legal frameworks for research involving adults lacking capacity in the UK.

8. Do you plan to include any participants who are prisoners or young offenders in the custody of HM Prison Service or who are offenders supervised by the probation service in England or Wales?

◯ Yes ◉ No

9. Is the study or any part of it being undertaken as an educational project?

◯ Yes ◉ No

10. Will this research be financially supported by the United States Department of Health and Human Services or any of its divisions, agencies or programs?

◯ Yes ◉ No

11. Will identifiable patient data be accessed outside the care team without prior consent at any stage of the project (including identification of potential participants)?

◯ Yes ◉ No

Go straight to content.

NHS
Health Research Authority

MRC Medical Research Council

Is my study research?

To print your result with title and IRAS Project ID please enter your details below:

Title of your research:

The Affect of Use of Bedtime Technology on The Body's Circadian Rhythm.

IRAS Project ID (if available):

275915

You selected:

- **'No'** - Are the participants in your study randomised to different groups?
- **'No'** - Does your study protocol demand changing treatment/ patient care from accepted standards for any of the patients involved?
- **'Yes'** - Are your findings going to be generalisable?

Your study would be considered Research.

You should now determine whether your study requires NHS REC approval.

Follow this link to launch the '*Do I need NHS REC approval?*' tool.

For more information please visit the **Defining Research** table.

Follow this link to start again.

Print This Page

NOTE: If using Internet Explorer please use browser print function.

About this tool Feedback Contact Glossary

Go straight to content.

Do I need NHS REC approval?

To print your result with title and IRAS Project ID please enter your details below:

Title of your research:

The Affect of Use of Bedtime Technology on The Body's Circadian Rhythm.

IRAS Project ID (if available):

275915

Your answers to the following questions indicate that **you do not need NHS REC approval for sites in England.** However, **you may need other approvals.**

You have answered ***'YES'*** to: Is your study research?

You answered ***'NO'*** to all of these questions:

Question Set 1

- Is your study a clinical trial of an investigational medicinal product?
- Is your study one or more of the following: A non-CE marked medical device, or a device which has been modified or is being used outside of its CE mark intended purpose, and the study is conducted by or with the support of the manufacturer or another commercial company (including university spin-out company) to provide data for CE marking purposes?
- Does your study involve exposure to any ionising radiation?
- Does your study involve the processing of disclosable protected information on the Register of the Human Fertilisation and Embryology Authority by researchers, without consent?

Question Set 2

- Will your study involve potential research participants identified in the context of, or in connection with, their past or present use of services (adult and children's healthcare within the NHS and adult social care),

including participants recruited through these services as healthy controls?
- Will your research involve collection of tissue or information from any users of these services (adult and children's healthcare within the NHS and adult social care)? This may include users who have died within the last 100 years.
- Will your research involve the use of previously collected tissue or information from which the research team could identify individual past or present users of these services (adult and children's healthcare within the NHS and adult social care), either directly from that tissue or information, or from its combination with other tissue or information likely to come into their possession?
- Will your research involve potential research participants identified because of their status as relatives or carers of past or present users of these services (adult and children's healthcare within the NHS and adult social care)?

Question Set 3

- Will your research involve the storage of relevant material from the living or deceased on premises in the UK, but not Scotland, without an appropriate licence from the Human Tissue Authority (HTA)? This includes storage of imported material.
- Will your research involve storage or use of relevant material from the living, collected on or after 1st September 2006, and the research is not within the terms of consent from the donors, and the research does not come under another NHS REC approval?
- Will your research involve the analysis of DNA from bodily material, collected on or after 1st September 2006, and this analysis is not within the terms of consent for research from the donor? And/or: Will your research involve the analysis of DNA from materials that do not contain cells (for example: serum or processed bodily fluids such as plasma and semen) and this analysis is not within the terms of consent for research from the donor?

Question Set 4

- Will your research involve at any stage intrusive procedures with adults who lack capacity to consent for themselves, including participants retained in study following the loss of capacity?
- Is your research health-related and involving prisoners?
- Does your research involve xenotransplantation?
- Is your research a social care project funded by the Department of Health and Social Care (England)?

If your research extends beyond **England** find out if you need NHS REC approval by selecting the *'OTHER UK COUNTRIES'* button below.