Research Paper for the

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By

Jana Fitz

The Negative Health Implications Caused By The Use of Computers and Smartphones

On closer inspection of high-energy visible light and radiofrequency radiation

Marshallplan-Jubiläumsstiftung
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Home University: Department of Media Technology at St. Pölten University of Applied Sciences

Host University: Department of Digital Cinema at Utah Valley University

Supervisor at home university: Dipl.-Sporting. Dr. Mario Heller

Supervisor at host university: Prof. Michael Harper

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Abstract

Digital information technology is prevalent throughout all our society. It shapes our daily lives and activities. According to Mary Meeker's "Internet Trend Report 2018", the average adult spends about six hours per day with digital devices. Along with the growing user population, health and safety issues associated with device usage have progressively grown. This digitalization of our everyday lives has consequences that have not yet been fully researched; however, there is evidence that intensive use of digital media devices may be harmful to human organisms in the long run. LED exposure occurs when monitors emit an excessive amount of blue light to which our eyes are not accustomed. Sleep disturbances and eye diseases can be the consequences of long term exposure. In order to be reachable, mobile phones use radiofrequency radiation which entails that radio masts are everywhere around us Society, as a whole, may be negatively affected by exposure to this radiation. This paper will examine how smartphones and computers work, how they influence human health, and how harmful effects of use can be minimized.

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1 Introduction

Mobile phones and computers have become an essential part of the modern world of communication. New technologies have simplified everyday life in unimaginable ways. Recent estimates showed that more than 77% of the world's population owns a mobile phone (Al-Hadidi, 2019, p. 2). But how dangerous are the biological effects on our bodies?

Recent studies on the dangerous effects of device use on the body are sometimes incoherent and contradictory, nevertheless this topic is not only difficult for an everyday user to assess, but also for scientists. It is remarkable how far humans have been able to develop over millions of years through adaptation. But the newest technologies of the last decades have changed so rapidly that the human body can hardly keep up with this development. One of the focal points of this work deals with the harmful effect of LEDs (light-emitting diodes) in screens of mobile devices and computers on the human body, in particular, the negative effects of LEDs on the eyes. Additionally, this paper will discuss electromagnetic radiation, especially high frequency radiation which is used in the communication of these devices. Since there are still no reliable long-term studies on these topics, physical damage caused by the ever-increasing use of technical devices cannot be ruled out. This paper shows some methods of effectively protecting oneself against harmful effects of device use, in addition to limiting one's time of use. The Internet, mobile telephones, and computers are an important part of today's world, and make our lives easier and richer in many ways. Nevertheless, this paper will draw awareness to the potential negative effects of long term use of electronic devices.

2 Optical Radiation

Smartphones and computers are mainly equipped with an LED (light-emitting diode) display, which has negative consequences on human health. The amount of irradiation with blue light-emitting diodes influences the circadian regulation of the sleep-wake cycle, damages the eye's retina, suppresses melatonin secretion, alters mood and cognitive functions, and contributes to fatigue. These facts are neglected because LED-based light sources have advantages over incandescent light sources, including flexibility, longer lifespan and lower energy consumption. Many companies recommend using light-emitting diodes to protect the environment, but often forget about the risks on human health (Tosini, Ferguson, and Tsubota, 2016).

2.1 Blue Light

Light is the visible range of electromagnetic radiation. It has wavelengths between 380 and 780 nanometers. "The visible light spectrum can be generally classified as short- (blue), medium- (green), and long-wavelength (red) light." (Smick, 2013, p. 1)

The electromagnetic radiation below the visible light spectrum is called ultraviolet (UV). It encompasses wavelengths from 100 to 380 nm. Radiation with longer wavelengths than visible light is defined as infrared (IR), it comprises radiations between 780 to 10,000 nm (Figure 1) (Smick, 2013, p.3).

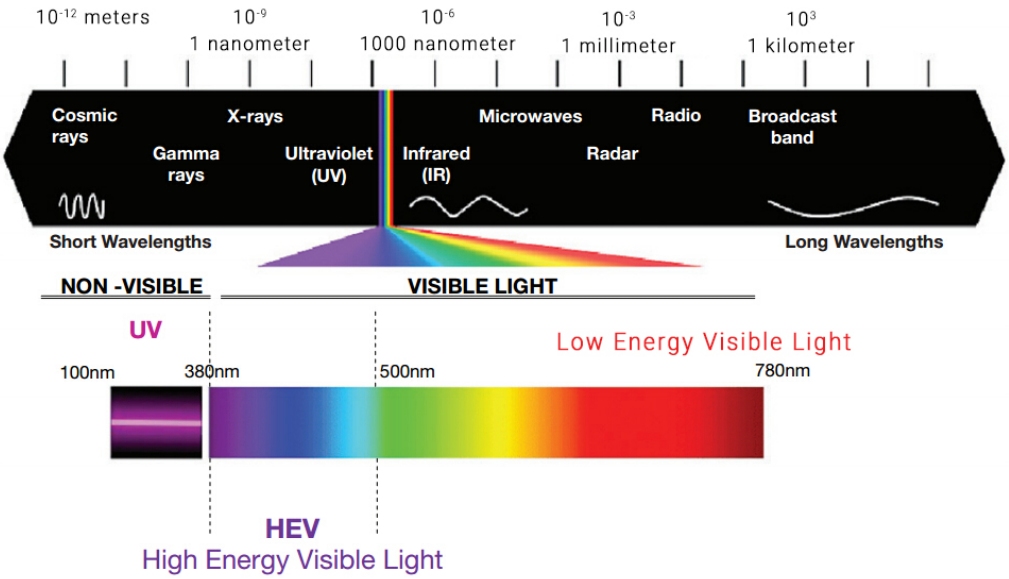


Figure 1: The electromagnetic spectrum and visible light (modified) (Smick, 2013)

All radiation carries energy. With light, the short wavelengths are the most energetic ones. Hence, blue light is renowned for high-energy visible (HEV) light. It begins at 380 nm and ends at 500 nm. It can either be found in a natural source, emitted by the sun, or as artificial light emitted, for instance, by screens (computers, smartphones, television, tablets) or LED lamps. Figure 2 represents newer technologies (Smartphones and LEDs) that emit significantly more blue light than older technologies (analog TV screens) (Smick, 2013, p.3).

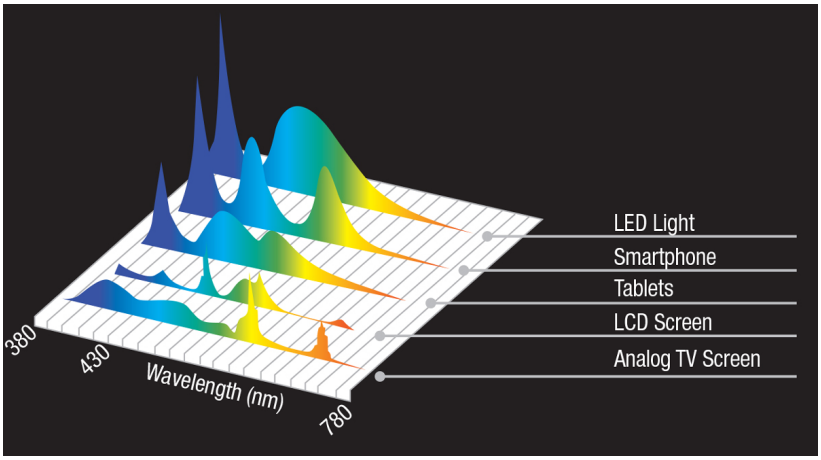


Figure 2: Comparison of blue light exposure from different light sources (Hefner, 2018)

2.2 LED Technology

The abbreviation for LED stands for light-emitting diode. In the past decade, the technology of LED lighting has developed rapidly. Nowadays, almost all conventional light sources are replaced by light-emitting diodes. They can be found in almost every light source, especially in displays. According to many product descriptions and test results, LEDs have many advantages. LEDs are energy-saving, long-lasting and can produce any light color. Nevertheless, LED lamps have some disadvantages. The high-energy visible (HEV) light penetrates far deeper into our inner eye, increasing the exposure enormously (Khanh, 2015, p.49).

Technical Structure

The LED chip is located in a small reflector cavity on the cathode. The gold wire, also known as bonding wire, maintains the current flow between cathode and anode. The lens is made out of epoxy resin, it ensures a good light distribution and holds all parts together. The LED chip is a semiconductor crystal and composed of two varying layers of doped semiconductor material. Figure 3 gives a detailed overview of the structure of an LED (Khanh, 2015, pp.49-50).

In the semiconductor layer, the anode consists of positive charge carriers. The negative charge carriers in the cathode are outnumbered. If both semiconductor layers are put under voltage, an electron flow occurs among them. To illuminate the LED, energy is released, small flashes of light are generated and photons are emitted, that's what humans perceive as visible light. The size of one light diode chip is only one millimeter long and emits a light spot, which is reflected through the cavity and thus guided into the upper half of the LED. The lens distributes the light in the room suitably, depending on its structure. The wavelength of the emitted light can be determined very precisely by doping the semiconductor material, which allows the light-emitting diode to be manufactured with almost every color

temperature. There are numerous suitable material systems on the market, so that light-emitting diodes can reproduce almost all colors monochromatically. These different combinations exhibit different levels of energy ("How Do Light Emitting Diodes And LED Lights Work?", 2017).

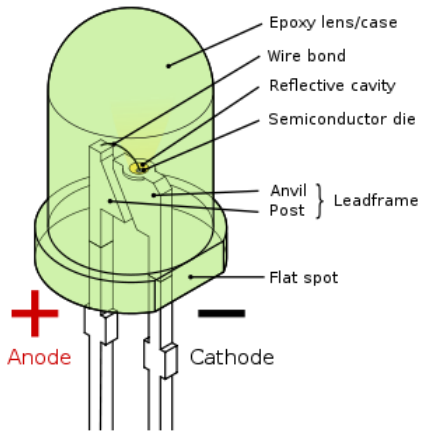


Figure 3: Structure of a Light Emitting Diode ("Light-emitting diodes Circuit, Working Principle and Application", 2017)

Only one color cannot be generated monochromatically: the color white. This requires additive color mixing or the physical process of luminescence.

Combination of Different Colored LEDs

One possibility way of generating white light is by superimposing the three primary colors green, blue and red. Within an LED, there are three semiconductor crystals of one of the three primary colors (RGB) each. This adjustment makes it possible to create any RGB color in addition to white, depending on how you control the brightness of each individual crystal. Since this method is considerably more expensive, it is commonly used for decorative and scenic lighting rather than general lighting (Khanh, 2015, pp.52-54).

Luminescence

A blue light LED is coated with a phosphor layer. The energy-rich blue light waves excite phosphors to glow. The combination of blue light mixed with the yellow phosphor layer appears as white light. Lighting can also be produced in warm white, cold white and neutral white: depending on the thickness of the phosphor layer. This method is most commonly used nowadays (Khanh, 2015, pp.49-66).

2.3 Smartphone Displays

There are two main display technologies, which are mostly used, when it comes to smartphones. A distinction is made between LCD, OLED.

2.3.1 LCD

LCD stands for “Liquid Crystal Display”. The technology is based on translucent liquid crystals. There are three of these crystals per pixel, each assigned to one of the three primary colors: red, green and blue. The LCD panel consists of four main layers: the protective layer at the outside, which is made out of glass or plastic and protects the components from getting damaged, the polarizing layer, which helps the crystal layer to deliver correct lighting, the layer with the liquid crystals and the backlight (figure 4). The liquid crystal layer is responsible that images are displayed with the correct colors. As soon as an electric current is passed through the crystalline layer, the colored liquid crystal cells "twist" to allow background light to pass through at different intensities. By filtering the neutral background light into specific color intensities plus the combination with adjacent crystals, the entire palette of millions of colors is created. The backlight are most commonly white LEDs, RGB LED backlighting exists too but is more expansive and therefore less common. The pixels in LCDs are addressed with the active matrix technology (Tyson, 2020).

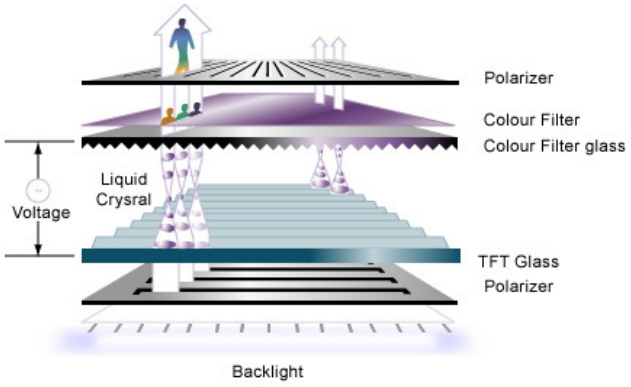


Figure 4: The structure of an LCD panel (Tyson, 2020)

Twisted Nematic (TN)

TN LCD is used in various cheaper devices because it has limited angles. The liquid crystals twist and untwist in different degrees to let light through. Without applied voltage to the TN liquid cell, the polarized light passes through at a 90-degree angle. If voltage applies, an untwisting of the liquid crystals occurs and the polarization changes and blocks the light's path. Almost any gray level or transmission can be achieved by correctly adjusting the voltage level. "Film Super-twisted nematic" has a clearly higher contrast level and an improved image sharpness compared to standard twisted nematic panels (Schiesser, 2012).

In-Plane Switching (IPS)

IPS are also based on the LCD standard; however, the electrode gate responsible for polarization is thinner. Therefore, the viewing angle stability is much better in comparison, you can see a true-color image from virtually any angle. This is why many high-priced smartphones rely on an IPS panel. IPS technology is mainly used in the professional field for computer displays (Schiesser, 2012).

2.3.2 OLED

OLED is the latest most advanced technology used in smartphones.

OLED stands for "Organic Light Emitting Diode" and works fundamentally different from LCD technology. Instead of using a backlight and making individual pixels transparent, the individual pixels themselves are the light source. OLED technology consists of three individually controllable LEDs per pixel. The way this technology works is quite simple: the power going to the organic upper layer is controlled by the transistor layer underneath. This has many advantages: no polarization filters are needed, the entire display does not have to be activated to illuminate certain areas, it has lower power consumption and the reproduction of colors is more natural. Some current panels are only 0.3 millimeters thick. The response time is in the microsecond range, making this technology significantly faster than TN or IPS displays (Mertens, n.d.).

2.3.3 Retina

The name Retina refers to a normal IPS panel, which has been given the marketing term Retina by Apple Inc. . Retina refers to the resolution of the display. Through research, Apple discovered that the human eye could not recognize more than 326 pixels per square inch. The entire product range was designed accordingly: from iPhone 4 to iPhone 8, displays with retina resolution has been used. The Plus models of the iPhone 6, 7 and 8 rely on higher resolutions, which is why Apple named the displays of these devices "Retina HD" (Schiesser, 2012).

Apple's iPhone X also demonstrates that the term Retina is marketing and not technology. It was presented with an unprecedented super retina display. Behind it, however, is only a slightly further developed OLED panel with a pixel density of 458 ppi (Schiesser, 2012).

2.3.4 Touchscreen

The majority of new smartphones use capacitive touch sensors. These are made of multiple layers of glass. The touchscreen is constructed from a two-layer coordinate network of electrodes, which are arranged as columns in one layer and as rows in the other. An insulating material is located between the electrodes, attached to the lower side there is a circuit mounted, which is constantly measuring the capacitance on the intersections of the electrodes. An insulting protective layer which is usually made out of glass, provides a protection for the electrodes and ensures a good surface so that the finger can easily slide over the material, it is applied as the top layer. Once the surface of the touchpad is touched by a finger, charges drain off because the human finger is electrically conductive. Thus, the electrostatic field between the electrodes is affected and there is a measurable change in capacity (Figure 5). At the moment the finger moves over the surface, the capacitance at the different electrode intersections changes and a microcontroller records every change and forwards it to the operating system. At the operating system, each touch is translated into a click signal or a movement signal. Since only conductive materials can change the electrostatic field, only substances such as human skin work on capacitive touchscreens, but not fabric or plastic. Capacitive touchpads are multi-touch-capable, as they can constantly measure the capacitance in the entire coordinate network and separately capture the entries of individual touches (Schiesser, 2012).

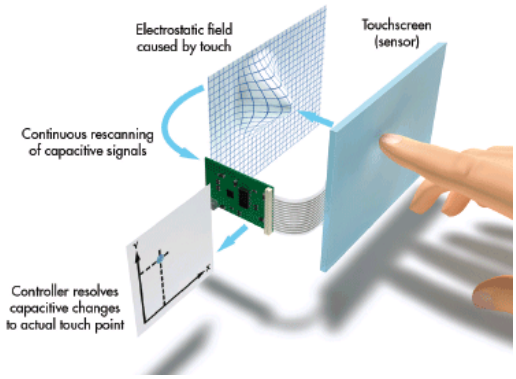


Figure 5: The structure of a capacitive touchscreen (Agrawal, 2010)

2.4 Impact on The Eyes

The American National Institute for Occupational Safety and Health found that spending more than three hours a day in front of the screen is harmful to the eyes. From this point on, exhaustion is caused by the effect of the screen. This effect is not only caused by eye-strain resulting from extended use but especially by the permanent irradiation of HEV light. The following are predominant symptoms experienced: loss of focusing ability, burning and tired eyes, double vision, blurred vision and headaches. Over time this can lead to astigmatism, nearsightedness, impartial vision, presbyopia, farsightedness and eye coordination problems (Angart, 2017, pp. 6-9).

Human eyes react well to printed matter due to the strong contrast to the background and the well-defined edges of the characters or letters. On screens; however, the sharpness of the characters or letters decreases towards the edge, creating greater eye-strain when reading digitally. In addition, the focus between the screen, mouse and keyboard is constantly changing (Angart, 2017, p. 8).

Light Damage in The Eye

Light exposure can cause pathological changes to ocular tissues due to the absorption of photon energy. When it gets absorbed it can be converted into heat or tapped via a photochemical reaction. Intensive exposure to high energetic light can cause thermal injury, while less exposure over a long time may cause the slow accumulation of harmful photochemical products which can lead to cell death.

The human eye is very effective at blocking ultraviolet rays from reaching the back of the eyeball where the light-sensitive retina is located. Only a small percentage (less than 1%) of UV light reaches the retina. The cornea blocks all wavelengths below 300 nm, whereas the lens absorbs wavelengths up to 400 nm. Both the cornea and lens protect the retina from damage. Despite this, a fraction of radiation with wavelengths shorter than

400 nm (320 nm) does reach the retina (Figure 6). This implies that the retina is mainly exposed to the most hazardous component of visible light, which is blue light (Smick, 2013, p.5).

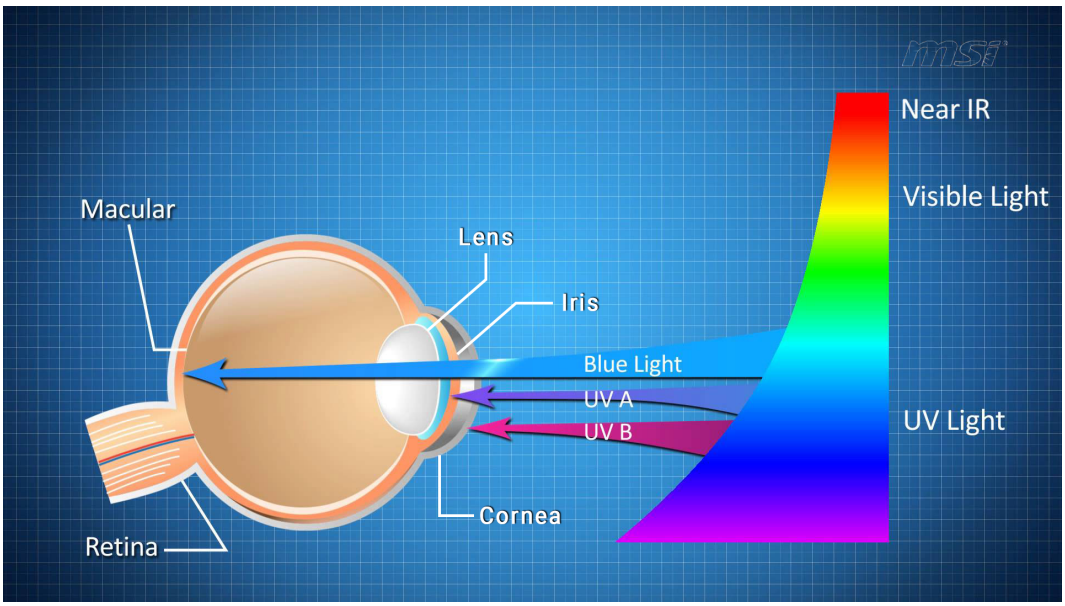


Figure 6: How light is absorbed by the human eye (modified) ("Macular Degeneration & Blue Light", 2012)

As a result of human evolution over millions of years, our eyes have adapted to the natural spectrum of light rays from the sun. The optical radiation from new technologies has only existed for a few years, and therefore the eye cannot protect itself sufficiently against it. The eye has built-in blue light protection to shelter the retina from the high-energy sunlight. The yellow spot, also called macula, is the center of the sharpest vision. The macula contains the highest number of cones where 90% of the daily vision takes place. Yellow dyes, in the macula, are responsible for filtering out the proportion of blue light. The distortion of the pupil, which primarily serves to adapt to different brightness levels, reduces the amount of blue light that falls into the eye. Therefore, the overall brightness of the room plays a prominent role. At night, if the display is the only light source in the room, the pupil opens wider and accordingly, more blue light penetrates to the retina (Irmer, 2018).

The 0.3 millimeter thick retina consists of an outer and an inner layer. On the outer retinal layer, where the light-sensitive rod and cone cells are located, blue light has an accumulative effect as the high-energy light causes chemical reactions. In response to blue light exposure cytotoxic molecules are formed, which accumulate in the cells of the outer retina. Additional blue light from mobile devices or LED lamps accelerates this process, causing photoreceptors to die. This increase in cell-death caused by excess blue light exposure accelerates macular degeneration and increases incidences of age-related macular degeneration (AMD) (Czerulla, Porteck, and Bielert, 2018). AMD is regarded as the main cause of severe visual impairment and blindness in industrialized countries, and has mainly affected people aged 50 and over. In the final stage of the disease, people perceive only a black spot in the central visual area. It is predicted that AMD will increasingly affect younger age groups as the average age of onset for AMD decreases (Smick, 2013, p. 7).

Eye Fatigue

Due to the high energy, blue light flickers more than other light. In addition, blue light produces more blare which can lead to headaches and eye fatigue after prolonged exposure. Previous studies have reported that almost 70% of adults in Europe, who use digital devices with illuminated displays regularly, suffer from symptoms of visual fatigue including impaired vision, irritated and dry eyes and headaches (“The hazards associated with blue light”, 2018).

Changed Circumstances

Another major problem deals with change of vision, due to changed circumstances. People spend more hours looking at objects close up than ever before. This is also developing into a problem among kids who begin school, "school myopia" refers to the increasing tendency of children to suffer from myopia (shortsightedness) after starting school. The eyes become overstrained when humans look at close objects over a long period

of time. If they do not spend enough time looking at distant objects, their eyes cannot relax and they lose the ability to focus quickly at different distances. The result of this occurrence is digital eye strain. Additionally, when looking at the display, people blink less thereby the cornea is moistened less frequently with tear fluid. This often causes tired, strained eyes and in the most serious case it can deteriorate the visual performance ("Blue Light", 2019).

2.5 How Blue Light Affect Sleep

The fact that blue light exposure affects sleep quality and fatigue is relatively well established; however, the magnitude of this effect is still greatly disputed in the scientific community. Literature review revealed the following:

Melatonin is a natural hormone produced by the human body through biosynthesis from serotonin to control the day-night rhythm. Throughout the day small amounts of melatonin are produced, when it gets dark, the production increases and this is leading to tiredness. For people with a fixed sleep rhythm, melatonin production already increases two hours before the start of their usual sleep phase. If visible light with a wavelength of 380 to 600 nm penetrates the eye, the natural production of melatonin may be interrupted, resulting in difficulty falling asleep and less restful sleep. This leads to the development of stress, depression, high BMI or high blood pressure. Studies carried out by the Transfer Centre for Neuroscience in Ulm also show that it is irrelevant whether people sit in front of the television, work with a smartphone or prefer to use an e-reader with lighting. In all cases, it was proven that the production of melatonin was delayed due to the irradiation with LEDs and the sleep rhythm was thus disturbed. In addition, the use of electronic media often leads to painful muscle tension, which then has a negative effect on sleep (Spitzer, 2017, pp.275-280).

2.6 Methods of Preventing Damage

The pathological health effects caused by high energetic light can be easily reduced with a few arrangements. In the following section, some exercises and methods for preventing damage are shown.

2.6.1 Blue Light Filter

A blue light filter is either an implementation on your device that changes the light emitted by your display or a physical barrier that repels and blocks out blue light.

Blue Light Filter Software Programs

In 2008, the first blue light filter application called f.lux was created. Michael Herf built this application for Windows computers to match the monitor color to the light in the room. The first version of f.lux synchronized itself with sunrise and sunset and changed the color temperature automatically. After this application worked successfully, researchers made more studies about blue light and found that orange light makes individuals calmer in the evening. Several companies like Google, Apple, and Microsoft integrated blue light filters into their operating systems ("The Ultimate Guide to Blue Light Filters - Apps, Glasses and Everything in Between", 2018).

These plugins decrease the amount of blue light that is displayed on the screen. The user can independently select how yellow or reddish the display should be. By now blue light filters can be activated manually at any time or controlled by a schedule. Some other software applications examples are: Night Light (Windows 10), SunsetScreen (Windows), Redshift (Windows, Mac, Linux), CareUEyes (Windows) (Tengyuen, 2019).

Regardless of the display technology used, the blue light component cannot be completely omitted. Both OLEDs and LCDs produce their color tones by mixing the primary colors red, green and blue. If blue were omitted, the

display would have a massive yellow, red or green cast, which would totally change the content. Because a cool (bluish) white appears brighter than a warm (yellowish) white, most manufacturers tune their displays to a cooler color to make the displays appear as bright as possible, which causes more blue light to be emitted (Tengyuen, 2019).

Blue Light Blocking Glasses

Computer glasses have been on the market for a few years now and they are becoming more and more popular. They are made with special spectrum control technology to absorb blue light. The glasses are equipped with yellow-tinted lenses, which increases the contrast and help to avoid eye strain. Companies that produce such glasses are Zeiss or Gunnar ("Die zwei Seiten des blauen Lichts", 2017).

2.6.2 Nutrition

A well-balanced diet can have a positive effect on the eyes. Two vitamins are particularly important for the eyes. The lens, the cornea and the vitreous fluid contain the highest concentration of vitamin C in the entire body. This high vitamin C level is important to prevent oxidation by free radicals, which would lead to cataracts. Vitamin A is a vital element for the retina as it is needed to build rhodopsin, which converts light sources into nerve energy. Furthermore, vitamin A is an important factor in night vision. It has been found that there is a clear connection between night blindness and a lack of vitamin A in the diet. Working on screens accelerates the consumption of vitamin A (Angart, 2017, pp. 50-52).

2.6.3 Vision Training

Near and Far Focus

Every now and then it is important to take a visual break and focus on something else for serval minutes. It is best to define three different points, with different distances, in the room and look back and forth between the different points.

Eye Chart Exercises

Two specific eye-charts have been developed for people who look into computers over a long period of time (Figure 7a, 7b). One of them should be placed behind the screen, thus the eyes get some movement by looking at the chart from time to time. Every 20 minutes the smallest symbols the person can easily see should be read for about 20 seconds. If the person chose the chart with numbers on it, she or he can either search for her or his birthday or another number combination every time to keep the exercise entertaining. The benefit of this exercise is that it uses the eyes more comprehensively instead of focusing them on the screen. The key to retaining perfect eyesight is to always change the focus point (Angart, 2017, pp. 24-30).

(a) Eye chart with numbers. (b) Eye chart with text

Figure 7: Eye charts for training the eyes (Angart, 2017, p.29)

3 Radiation

3.1 Electrosmog

Each molecule and atomic particle has an electromagnetic field, therefore humans are constantly exposed to electromagnetic influences. The sun and the earth generate electromagnetic fields. Just four generations ago, almost all these naturally occurring electromagnetic fields were harmless to humans ,either because they were essential for life, or because they were too weak to influence the body. But our natural environment has evolved into a densely woven network of multiple radiating sources since electric power and its modern manifestations were developed. This excessive radiation density is known as “electrosmog”. It is inaudible, invisible and only noticeable by a very small number of people, it has become a constant threat to human health (Poser, 2017, pp. 8-15).

3.2 Electromagnetic Radiation

> “Radiation is the process through which energy travels (or “propagates”) in the form of waves or particles through space or some other medium. The term “electromagnetic radiation” specifically refers to the wave-like mode of transport in which energy is carried by electric (E) and magnetic (H) fields that vary in planes perpendicular to each other and to the direction of energy propagation.“ (Thomas, 2013, p. 37)

Electromagnetic waves differ in their wavelength and in their frequency. This applies to the relations between wavelength and frequency:

$$\lambda = c/f$$

$$Wavelength = speed\ of\ light\ /\ frequency$$

The wavelength (λ) is the distance between successive crests of a wave, it is related to the frequency, the higher the frequency the shorter the wavelength. The waves travel at the speed of light (c) in air and free space, in less conductive media, such as body tissues, waves travel more slowly. The frequency (f) is quantified in the unit hertz (Hz) and describes the number of cycles per second. That implies, the higher the frequency the shorter the wavelength. Through the various wavelength the electromagnetic rays propagate differently and so they have different effects on organisms. Light and thermal radiation can be perceived by humans, unlike UV light, which is beyond the range of our senses, and can only be noticed through its effect, sunburn. Electromagnetic fields remain unnoticed, we neither perceive them nor notice their effects (Thomas, 2013, p.37).

Between a charged point (positive or negative) and its environment, an electric field builds up, which has enough power to cause current to flow.

> "Electric fields are created by differences in voltage: the higher the voltage, the stronger will be the resultant field. Magnetic fields are created when electric current flows: the greater the current, the stronger the magnetic field. An electric field will exist even when there is no current flowing. If current does flow, the strength of the magnetic field will vary with power consumption but the electric field strength will be constant." (World Health Organization, 2016)

Electromagnetic fields (EMF) are produced by natural sources, like the geomagnetic field from the earth or the local build-up of electric charges in the atmosphere associated with thunderstorms and human-made sources. All the electricity that comes out of a power socket, X-rays to diagnose broken bones and higher frequency radiowaves to transmit information, either via radio or mobile phone stations or TV antennas, are man-made electromagnetic fields. The different types of electromagnetic radiation vary

in their wavelength. All electromagnetic fields with different frequencies are summarized by the term electromagnetic spectrum. The spectrum is subdivided into two areas, the non-ionising radiation and the ionising radiation. Ionisation is the process in which an electron is given enough energy to break away from an atom (Falsaperla & Rossi, 2008, pp.1-3).

3.3 Non- Ionising Radiation

Ionising Radiation

Ionising radiation is strongly energetic. It has enough energy to cause chemical changes by breaking chemical bonds. This can cause damage to living tissue. Gamma-ray radiation and X-ray, which are at the upper end of the electromagnetic spectrum (Figure 8), have very short wavelengths (less than 10 picometers) and very high frequencies (above 10 exahertz or $>10^{19}$ Hz). Ionising radiation has many medical, industrial and military uses. Nevertheless, new digital devices such as mobile phones operate on the basis of ionising radiation (Guilfoyle, 2017).

Non-ionising Radiation

Non-ionising radiation is found at the long wavelength end of the spectrum, it is unable to break chemical bonds but may have enough energy to excite molecules and atoms causing them to vibrate faster. It ranges from very low frequency radiation 0 Hz up to 950 THz ultraviolet A. It includes electric and magnetic fields, radio waves, microwaves, infrared, ultraviolet, and visible radiation (Guilfoyle, 2017).

Static fields are the part of the non-ionising radiation with the lowest frequency rate. They have the frequency zero and belong to the DC alternating fields, i.e. there is no polarity reversal and the magnetic and electrical components are separated from each other. An example of this is the earth's magnetic field (Casanova, 2017, pp. 3-7).

The low frequency range covers the low frequencies from 1Hz to 30 kHz. This frequency range can be found in traction current for railway lines, and in everyday household applications. The low-frequency radiation is used by the current supply (50 Hz) and by the use of kitchen appliances and machines. They belong to the alternating fields and have separate magnetic and electrical components ("What are the risks of non-ionising radiation?", 2019).

The high-frequency range includes electromagnetic fields in the frequency range from 30 kHz to 300 GHz. This paper will mainly focus on this area of the spectrum, the high-frequency waves. The high-frequency radiation is mainly used for the transmission of data (mobile communications, radio, wifi, etc.), but also for heating, such as microwaves. This indicates „that exposure to electromagnetic fields in this frequency range can warm up exposed tissues because these absorb the radio wave and microwave energy and convert these into heat. The frequency level determines the depth of penetration into the body." ("What are the risks of non-ionising radiation?", 2019)

The thermal effect is caused by the excitation of water molecules (dipole molecules) and free charge carriers in body tissue. In addition to the thermal effects, other athermal effects are also suspected, such as influences on the hormonal system, sleep behaviour and effects on well-being ("What are the risks of non-ionising radiation?", 2019).

Finally, infrared radiation also belongs to non-ionising radiation. Infrared is used in a variety of applications. Among the most well-known are night vision equipment, heat sensors and thermal imaging (Berz, 2003, p.23).

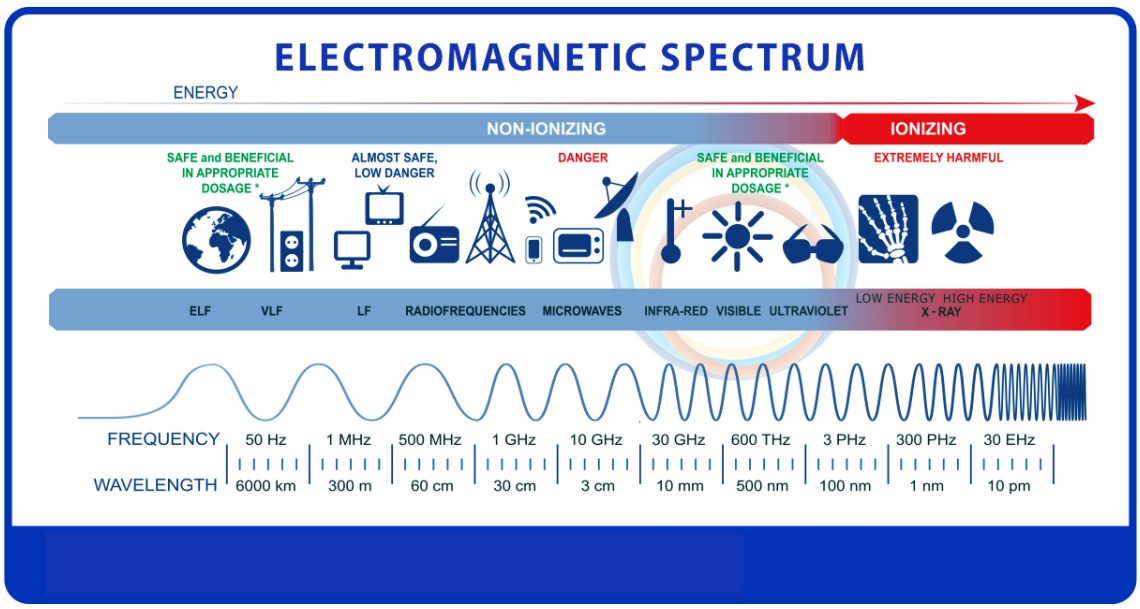


Figure 8: Electromagnetic spectrum (modified) (“Types of Ionizing RadiationIPolimaster”, 2018)

3.4 Radiofrequency Radiation

Radiofrequency (RF) electromagnetic fields (EMR) are mostly produced intentionally for transmitting information. Radio, television and mobile services use transmitting antennas. The 18.000 cellular radio stations in Austria enable data to be sent and received. Phone calls, as well, can be made anywhere with mobile phones. The radius of a radio cell, in rural areas, can be several kilometers, whereas in conurbations there is a tighter network of smaller radio cells. The transmitting power base stations vary between 10 and 50 watts with ranges from 100 meters to 30 kilometers. Frequencies between approximately 870 MHz and 2690 MHz are used for mobile radio, depending on the network provider and mobile radio standard (GSM, UMTS or LTE). Unlike television and radio stations, mobile radio antennas do not radiate equally in all directions. With the help of reflectors, the field is bundled so that cone-shaped radiation occurs in one main direction. (Figure 9) As a result, the emissions in immediate surroundings are significantly lower than, for example, televisions or radio stations ("EMF-Portal I Mobilfunk" , 2018).

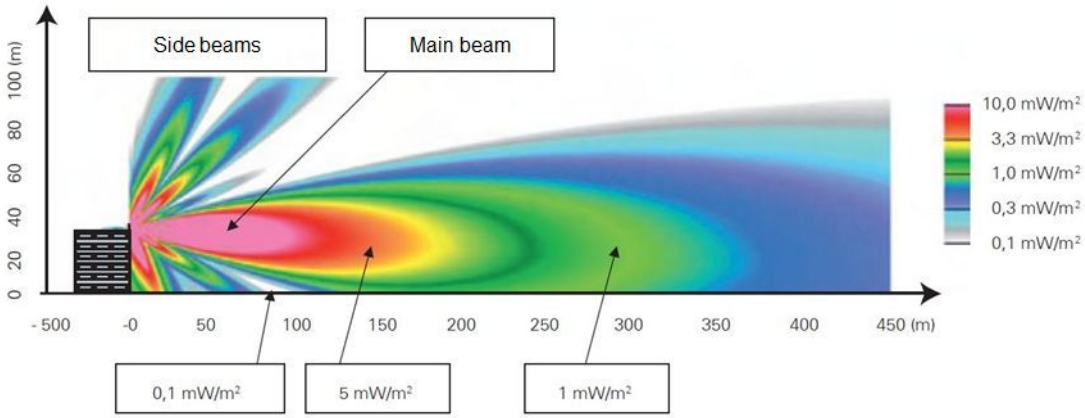


Figure 9: The vertical alignment of an antenna for mobile communications. Non-uniform field distribution on the ground in the vicinity of the antenna, with areas of low power density (bottom left), given in mW/m²(Ridder,2018)

The Use of Mobile Phones

Whereas base stations continuously emit radio signals, mobile phones only emit signals while having a phone call, transmitting data or sending a message. If no call is being made and no data is transmitting, the phone is on standby mode. The phone receives signals continuously from the base station but only sends a message every couple of minutes to stay connected. The mobile phone is the strongest high-frequency field source to which humans are exposed in their everyday environment during active data traffic or call set-up. A transmitting antenna has much higher transmitting power than a mobile phone, but the distance between body and cell phone is far less (particularly the distance to the head) than body and antenna. The body is not uniformly exposed. The head and the parts of the body where the phone is carried are the parts exposed to radiation, which is considerably worse for human health. The transmission power depends on the connection between the mobile phone and the base station. If the connection is poor (e.g. within the shielding metal shell of a car), then transmitting power is upregulated. Nowadays mobile phones work under the global LTE, GSM or UMTS standards. The transmission power can reach a peak value of 2 watts in the GSM 900 network and 1 watt in the GSM 1800 network ("EMF-Portal I Mobilfunk" , 2018).

> “To specify the absorbed energy in body tissues, which arises from the emitted electromagnetic fields of mobile phones and smartphones, the specific absorption rate(SAR) is used. In the tissue the energy is mainly converted into heat.
>
> Therefore, the SAR is expressed in watts per kilogram of tissue (W/kg) and is averaged over a six-minute exposure interval in corresponding measurements or simulations. During this time, an equilibration between the energy input and the heat dissipation in the tissue has been reached. “ ("EMF-Portal I Mobilfunk" , 2018)

By specifying different body masses, standardized SAR determination procedures are used to distinguish between exposure of the whole body (whole body exposure) or parts of the body (partial body exposure). Due to the proximity of a mobile phone to the body, a distinction is usually made between the situations "mobile phone on the ear" and "mobile phone worn on the body". The SAR limit for mobile phones is 2 watts/kilogram of tissues. The maximum SAR information has to be written in the product manual ("EMF-Portal I Mobilfunk" , 2018).

In the following table, the three best-selling mobile phones are compared Table 1.

Specific Absorption Rate – SAR Comparison		
Manufacturer / Model	SAR Value (At the ear)	SAR Value (On the body)
Apple - iPhone 7 (Model A1778)	1,38	1,34 (Measurement distance: 0.5m)
Apple - iPhone X (Modell A1901)	0,92	0,95 (Measurement distance: 0.5m)
Samsung - Galaxy S10 (SM-G973F)	0,48	1,59 (Measurement distance: 0.5m)
Huawei – P20 Dual SIM (EML-L29)	0,76	1,26 (Measurement distance: 0.5m)

Table 1: Specific Absorption Rates (SAR) for four specific mobile phones ("BfS-SAR Search", 2019)

3.5 Impact on Human Health

What are the Health Effects of Radiofrequency Radiation Exposure?
"Exposure to sufficiently high levels of RF EMR can heat biological tissue and potentially cause tissue damage. The amount of environmental RF EMR routinely encountered by the public is too low to produce significant heating or increased body temperature." ("Radiofrequency radiation", 2017)

There is no established scientific evidence that the use of mobile phones constitutes a human health hazard. A study by the US National Toxicology Program exposed groups of lab mice and rats to radiofrequency energy used in mobile phones. An increased risk of infrequent heart tumors, as well as a possible increased risk of certain types of tumors in the brain and adrenal glands caused by the exposure to radiofrequency radiation was found in the study by male rats. Among the female rats and male and female mice, no clear increased risk was reported. Because of limited evidence, and some other aspects of this study, it leaves it difficult to understand what these findings might mean for the human health ("Radiofrequency radiation", 2017).

The International Agency for Research on Cancer has classified radiofrequency fields as possible carcinogens for humans. Nevertheless, the WHO (World Health Organization) has coordinated more rigorous long-term studies in this field, which are yet to be published ("Mobile phones and health", 2017).

Does RF Radiation Cause Any Other Health Problems?
Exposure to a high dose of radiofrequency radiation can lead to injuries through heating. For instance, people received severe burns from radar equipment with great amounts of RF radiation. Another harmful effect is RF hearing, also known as microwave hearing effect. This phenomenon occurs near powerful sources of pulsed radiofrequency radiation. Some people are

able to perceive pulsed radiofrequency reproducibly as click noises, but this does not appear to be causing long-term health issues (The American Cancer Society medical and editorial content team, 2018).

3.6 Methods of Preventing Damage

Considering that evidence on the health implications of mobile phone use is still largely inconclusive, it is recommended to avoid excess exposure until its effects on health are better understood. The most efficient ways to reduce RF radiation are to increase the distance between the user and the mobile phone (especially by call-setup), by holding the phone one arm's length away during the first few minutes or by using hands-free equipment. Otherwise, it is always healthier to send a text message instead of making a phone call. Limiting the duration of the call and making calls at locations with good reception are also encouraged.

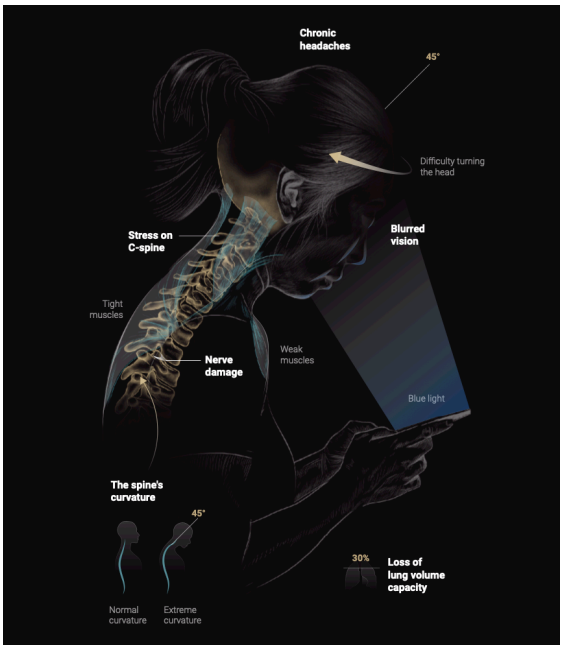
In addition, it might be convenient to avoid jobs with increased RF exposure. Users should follow the manufacturer's advice regarding spacing the phone from the body. Old mobile communication devices transmit data using the GSM standard. The GSM standard generates a higher level of radiation during connection then the UMT or LTE standard that most modern mobile devices use. When using UMTS or LTE standard, the mobile communications device operates using the lowest transmission power at first and then increases it if more power is needed. The GSM operates in the opposite way, it uses maximum power when setting up the call. This indicates that using a modern mobile phone has an advantage over older models. When purchasing a new device, it is useful to look out for the lowest possible SAR value. Sources of RF radiation are so strongly represented in the modern environment, it is impossible to completely avoid exposure to them (The American Cancer Society medical and editorial content team, 2018).

Products have been developed to ensure protection against electrosmog. One example is VIVOBASE. The human body consists mainly of water and is controlled by bioelectric impulses. Electrosmog can disturb these natural processes through the penetration of radiation into the body. Waves go through the body and inhibit an optimal cell supply. VIVOBASE acts like a protective shield, it generates an electrostatic field that positions the body's own water molecules in the upper skin layer (orientation polarization). Due to the asymmetric structure of water they have a permanent electrical dipole moment, i.e. there is one positively charged side (both hydrogen atoms) and one negatively charged side (oxygen atom). The electrostatic field prevents the water molecules in the body from following electromagnetic radiation. This means that the body cells can absorb sufficient water again and the damaging effect of electrosmog is greatly reduced. Living organisms can thus maintain their health despite the radiation environment. The generated field imitates a natural field and is therefore harmless for the body. Scientific research by Bion, Institute for Bioelectromagnetics and New Biology, Ltd., in Slovenia, confirm the effectiveness of VIVOBASE products ("Vivobase Home", 2017).

4 Physical Impact

4.1 Text-neck

Multiple studies have been conducted to analyze the correlation between the use of cell phones and neck, shoulder and back pain. Research has shown that prolonged neck flexion is linked to the occurrence of musculoskeletal problems in the neck, often referred to as text-neck syndrome (Figure 10) (Yoon et al, 2020).



"'Text neck' refers to pain symptoms on the neck and neighboring regions during or after prolonged looking down posture that smartphone or tablet PC users typically make when they are text messaging. Findings in previous research indicate that smartphone users would make a head flexion of 33° to 45° from vertical in average when using smartphones in sitting or standing." (Lee, Kang, and Shin, 2015)

Figure 10: Illustration of the text-neck syndrome (Robles, 2019)

In 2019, Hyeson Han and Gwanseob Shin conducted a naturalistic data collection study in which the head flexion angle of young smartphone users was recorded simultaneously for 8 hours using a wearable motion sensor. "Participants spent 125.9 minutes (median usage duration) on their smartphones with significantly larger head-down tilt ($p < .05$) than when they were not using the phone." (Han, Lee, and Shin, 2019) This unnatural flexion puts the user at risk of pinched nerves, causes muscle tension and can, ultimately lead to a herniated disc. The study found out that the users maintained greater head flexion during texting than when they were performing other tasks with their phone. The head flexion angle is also

significantly larger when conducting two-handed texting than only using one hand for it. Furthermore, men tend to flex their heads more but woman reported to have higher musculoskeletal pain compared to men. This might be due to the body structure difference between men and women (Toh et al., 2017).

The average head-weight of an adult man ranges from 3800 to 4100 g, of an adult woman from 3200 to 3600 g. The weight on the spine increases enormously when flexing the head forward (Figure 11). Only a 15 degrees flexion causes a 12kg heavier weight on the neck which adds unnecessary strain to the neck. By increasing the angle to 30 degrees the weight increases to 18kg, while a 45-degree angle adds up to 22kg extra weight.

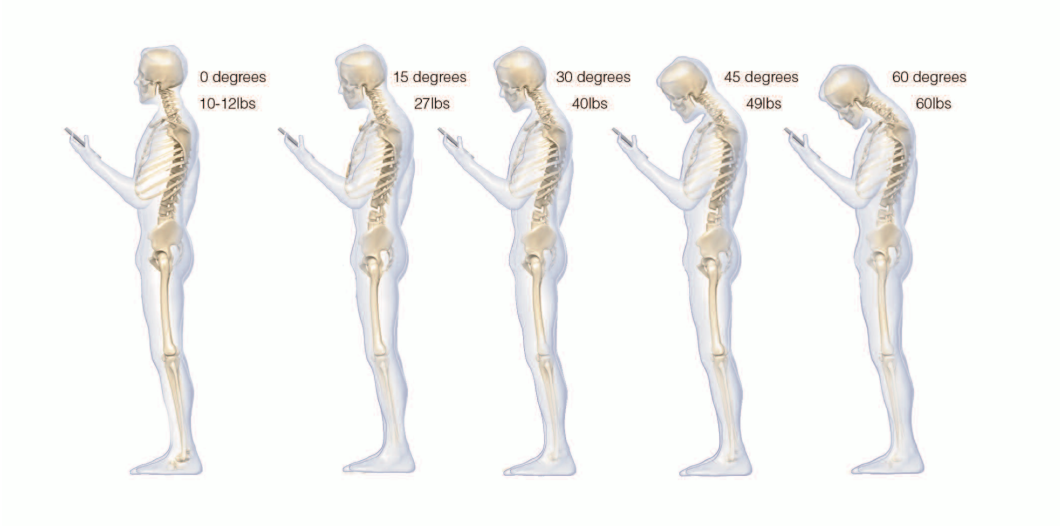


Figure 11: A 15 degrees flexion causes a 12kg heavier weigh on the neck which adds unnecessary strain to the neck. By increasing the angle to 30 degrees the weight increases to 18kg, while a 45 degree angle adds up to 22kg extra weight (Hansraj n.d.)

In order to have good posture, the head should be above the shoulders, with ears aligned. The shoulders blades should be retracted and the shoulders should be over the hips. With correct alignment, the load on the spine is diminished. If people only spend 2 hours a day with their heads tilted down, they spend cumulatively 730 hours a year with excessive strain on the cervical spine. This stress on the body may lead to tears, degeneration, early wear, and possible surgeries. It is essential that users look at devices with a neutral spine and avoid spending hours hunched over their smartphones (Hansraj n.d.).

5 Conclusion

From all that has been stated it can be conceded that smartphones and computers are not blessing nor a curse. Instead electronic devices should be used with caution. Spending the whole day in front of a device should be avoided because it has not yet been sufficiently scientifically proven whether it is really harmful to the human organism or not. This thesis clarifies that it is important to dispute with these topics and gives potential solutions on how to reduce the negative influences on the body. The result of this thesis, besides the clarification of research, is to present simple solutions every individual can do to reduce the damaging effects of modern technology on their body.

Considering the optical radiation, the biggest hazard is blue light. Blue light is a high-energy visible light. The wavelengths of blue light are shorter than other optical light wavelenghts. This allows the waves to penetrate deeper into the eye and cause greater damage. As a result of the replacement of conventional light sources, the amount of blue light in the world is increasing rapidly. Almost every display in modern society is based on LED technology. Therefore, this paper shows several methods everyone can do to prevent damage on the eyes and on the human organism. By using blue light blocking glasses or by installing a blue light filter app on the smartphone or computer, your vision can be easily protected. You can have a good influence by the right nutrition, such as vitamin A and vitamin C or by training the eye muscles where to focus through exercise routines.

When using radiofrequency radiation, device users should be cautious. The frequency of the non-ionizing radiation does affect the body cells in certain ways and should not be ignored. Through the ever-advancing technology, the possibilities for protecting oneself is increasing. For example, there is

VIVOBASE, a device that acts like a protective shield against electrosmog in the house. The most efficient way to reduce radiofrequency radiation is by increasing the distance between the user and the radiant source. For instance, during a call-setup a user should put their phone at one arm's length away, by this small distance their cells will be less irradiated. The limitation of the devices is the best way to maintain health.

In addition to blue light and electrosmog the physical side effects were also discussed. Doctors assume that the increased use of electronic devices leads to poor posture and therefore to more back problems. To avoid the increased occurrence of back issues, users should not hunch over their devices, the should pay attention to have a neutral and straight posture while looking at the displays. It is slowly going in the direction that doctors prophylactically demonstrate plenty of exercises and tips to counteract damage to patients.

In a few years, a better understanding of the subject will be available. All someone can do for themselves is to minimize the time using their devices. Nevertheless, one must also keep in mind that it is not in the economic interest to define the lucrative use of the media as bad.

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