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Effect of correlated colour temperature on students' alertness, reading speed and comprehension

Amal Abdullah M Alkhabra

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Supervisors

Professor Stephen Westland
Dr Vien Cheung

The University of Leeds
School of Design

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I. Abstract

This study examines the effect of dynamic lighting systems to boost reading performance. Recently, several educational research have revealed that lighting has a potential effect on various psycho-physiological phenomena. Different lighting conditions have a significant impact on cognitive function, hormonal production, mood regulation, and even circadian rhythms (and thus, on sleeping patterns). The pedagogical effects of these discoveries may be profound, particularly as regards designing the teaching environment, which has been recognized for a long time as having a considerable influence on educational results. Hence, the more control educators command over the learning space, the more that space may be optimized to achieve predesigned objectives. So far, the majority of the research has focused on the positive effects of dynamic lighting systems. Studies have shown that variations in correlated colour temperature (CCT), can make a big difference to students' attention span, concentration, motivation, and even behaviour. Consequently, scholars are beginning to pay serious attention to the ways in which artificial lighting systems can be amended to optimize learners' performance.

The purpose of the current study is to investigate these phenomena in relation to students' reading comprehension and speed. The current study specifically evaluates the impacts of LED illumination on 30 undergraduate students who were pre-selected based on specific criteria (did not have pre-existing health disorders, nor did they have eye problems or learning difficulties). The research project was carried out in two phases: laboratory and field study.

The research was conducted in a psychophysical laboratory. The test evaluates the following CCTs: 6500K, 5000K, 4000K, 3000K, and 2500K, at three brightness levels (275, 475, and 613lux). Students' reading speed and comprehension were evaluated in two ways: first, through printed reading exams, and second, using the Karolinska Sleepiness Scale (KSS). After determining the benchmark for the duration of the experimentation, recruiting the participants, and determining the tools for assessing the study variables; the experiment started. The experimentation was executed over 3 days (1-hour session each day) to investigate the effects of the five different light settings.

Keywords: colour temperature, alertness, reading speed, reading comprehension, student performance, effects of colour temperature on academic performance.

Glossary:

Abbreviation/Term	Definition
CCT - Correlated Colour Temperature	The temperature of a Planckian radiator whose colour most closely approximates that of a given stimulus at specified brightness and viewing conditions. This is registered in Kelvin (K) and gives the information of the colour quality of the light.
KSSA - Karolinska Sleepiness Scale for Alertness	It is a modified version of Karolinska Sleepiness scale (KSS), which was applied for alertness measurement of the respondents in the experiments on light and cognition.
CRI - Colour Rendering Index	A metric that evaluates how successfully certain colors of objects are reproduced when viewed under a light source other than the sun.
ipRGCs - Intrinsically Photosensitive Retinal Ganglion Cells	Photoreceptors and the cells which are part of the retinohypothalamic tract and have roles such as circadian rhythm and sleep regulation among others.
LED - Light-Emitting Diode	A semiconductor that produces energy in the form of light when an electric current passes through it. Since they are energy efficient, long lasting, and can be used in a variety of artificial lighting systems, LEDs are popular.
Illuminance	The quantity of light per unit area. It is the measure of brightness felt by the eye from a surface in a room.
CER - Circadian Effective Radiation	This is a measure of how light affects the circadian system while more specifically the sleep-wake cycle and biological rhythms.
CIL - Circadian Illumination Level	Exposure to light characterized by intensity and spectral composition that is needed to activate the circadian functions of the body.
VL - Variable Lighting	A close-up of the work settings may exhibit a dynamic control over artificial lighting shifting its intensity, color temperature or other parameters to increase levels of focus for a task, or, relaxation and passive states.

Contents

III. Introduction

From the sun to a candle, from an electric bulb to the stars - light is a wonderful thing! It brings us warmth, lights up our way, and gives us a sense of safety. Let us cherish it for it plays a crucial role in our existence. Appreciate light for its beauty and its importance! As humanity has evolved, human beings became more and more acquainted with natural light. To put it another way, light has become a necessity for human life since it has a major part in controlling an array of physiological activities, such as wakefulness and rest. Moreover, light plays an important role in mood and cognition, enabling a wide array of hormonal production such as cortisol and melatonin (LeGates et al. 2014). Melatonin is a hormone that can be naturally found in the human body. The secretion and inhibition of melatonin help the human body to regulate its responses during the typical day and night cycle, i.e., the sleep and wake cycle (Claustrat et al. 2015). The presence or absence of light is a crucial sign, so the human body engages in the sleep and wake cycle and acts accordingly. The absence of light informs the body that the night has just begun. Consequently, the body's melatonin secretion goes up, which initiates a series of signals that prepare the body for sleep. On the other hand, the presence of light arouses the signals needed to wake a person up. These functions justify why most individuals, at least from an evolutionary standpoint, are active and stay awake during the day and tend to be less active and show a need to rest at night hours before starting another sleep-wake-night-day cycle (Siegel 2003).

In conclusion, the human body manifests regular physiological responses to the environmental stimuli that signify daytime; and other different physiological reactions linked to the recognition of night-time signals. This inherent human ability is one of the most cited arguments regarding the influence of diverse illumination conditions on cognitive activities.

Previous studies have adopted various approaches to explore light and related concepts, such as the examination of Poldma (2009). This research delved into the possibility of integrating colour and light theories within contexts of human experience in internal areas. While Haxeltine and Prentice (1996) presented a general approach to the light-use efficiency of primary production. Other research has examined the use of light to regulate alertness and entrainment. Figueiro et al. (2018) concluded that new professions, like personal light health coaching, and software applications to monitor light–dark exposures and provide recommendations for correcting circadian disruption, should be created. Various methods exist to elucidate the type, appearance, or emotions that people experience when presented with different levels of light. Other approaches have focused on the effect of light on human biological functions, for example, the melatonin-inhibition reaction. The variability of light's wavelengths impacts biorhythms, brain activity, respiration rates, pulse, and blood pressure. The wavelength (λ) of light can have a significant influence on brain activity and performance, and restricting light exposure through λ-controlled sources, like blue light for working or sleeping, can lead to better learning outcomes and reaction time, as well as to improving mental well-being. However, unrestricted bright light exposure has been found to hinder attention and memory and reduce motivation. Consequently, using light sources with suitable λ-restrictions can potentially allow individuals to elevate their cognitive performance and strengthen their mental health.

Previous research has suggested that light, both in terms of intensity and quality, has a major role in influencing human sleep patterns, biological clocks, and emotions (Mott et al., 2012). Additionally, the type of light that people are exposed to has a significant effect on both their behaviours and their mood. For example, early morning light can be beneficial for mood, sleep, and cognitive performance, whereas less exposure to bright light at night has been linked to depression, sleep disturbances, and increased caffeine intake. Therefore, it is very important to understand the influence that light has on human biology, both to make the most of its advantages and to try to prevent its harmful effects. In Sloane et al.'s (2008) study, it was observed that morning and evening light exposure helps to improve sleep quality and alleviate depression symptoms in elderly individuals. This suggests that light therapy may be an effective cure for sleep issues and depressive disorder in this population. Bedrosian and Nelson's (2017) study demonstrated that the time of light exposure can have a substantial effect on brain activity and attitude. Their research indicated that bright light in the morning amplifies alertness and cognitive performance, while bright light at night can disturb circadian rhythms, resulting in fatigue and poor sleep quality. Mead (2008) suggested that sunlight carries a range of health advantages. Their research revealed that sunlight can enhance the immune system, elevate mood, and lower stress levels. Moreover, sunlight exposure has also been associated with a diminished hazard of some diseases, such as osteoporosis and particular kinds of cancer. This implies that spending time in the sun outdoors can be beneficial for overall health and wellbeing.

In a systematic review, Kompier et al. (2020) reveal that while dynamic light scenarios hold promise for human functioning, especially in terms of providing an increased light dose during the day and supporting circadian rhythms, consolidated strategies for their design and assessment are currently lacking. Further work is needed to develop a vocabulary and framework to define the rationale for dynamic lighting as well as sound procedures to test their effectiveness. Thus, this review highlights the need for additional research in this field to fully grasp the potential benefits of dynamic lighting scenarios for various applications and user groups.

As light has been found to affect various human functioning, including cognition, mood, circadian rhythms, and vision, its implicit implications on academic achievement and learning cannot be dismissed or underestimated. Previous studies have demonstrated that specific characteristics of light can increasingly impair cognitive and visual performances (Konstantzos et al., 2020). Some of these features encompass dry-erase whiteboards and interactive whiteboards. Most of the studies that have been conducted to assess the implications of correlated colour temperature (CCT) have been conducted on adults. (Borbély et al. 2021) stated that correlated colour temperature (CCT) refers to the temperature of a Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions.

The findings of these studies have demonstrated that CCT can increasingly enhance the cognition and attention of individuals. In 2017, Hartstein conducted two experiments to explore the conditions by which light colour temperature impacts some cognitive abilities. The participants were asked to respond to cognitive tests, including mental rotation, task switching, and sustained attention. The findings revealed that, under the dynamic lighting condition, participants showed a significant decrease in reaction time on a measure of sustained attention, beyond those of a static light source at a cooler colour temperature. Other results showed that preschool-aged children exposed to cooler colour temperature light showed significantly greater improvements in cognitive flexibility, demonstrating that the relationship between light and cognition is present from an early age. The results of this study suggest that male participants were the only ones who exhibited an increase in sustained attention. This finding suggests that gender may play an important role in attentional processes. Future research should investigate this phenomenon in more detail, as well as its implications for our understanding of attentional systems.

Different investigations such as Yang & Jeon (2020), Zhang et. Al. (2020) have revealed that reduce CCT was related to self-reported efficiency, good feelings, restfulness, visual solace, and higher fulfilment. However, contradicting findings regarding the implications of CCT on cognitive performance can be found because some studies have indicated no significant effects of CCT on cognitive performance in both young and older adults. Other research experiments have investigated the effects of CCT of light on vitality and attention in the afternoon versus morning. The outcomes of this study demonstrated that CCT of light plays an essential role in enhancing mental well-being and alertness.

Furthermore, previous studies such as Siraji et al. (2022) and Beaven and Ekström (2013) both found that exposure to short-wavelength light can improve cognitive performance and alertness. Scholars increasingly believe that blue light can affect attention through the intrinsically photosensitive retinal ganglion cells (ipRGCs). When stimulated, ipRGCs increasingly send signals to the suprachiasmatic nucleus through the retina hypothalamic tract. The process ultimately leads to the suppression of melatonin (Hartstein et al., 2018). Following an increased exposure to light, the ipRGCs' signals filter out into a broad range of brain regions, such as dorsolateral and cingulate cortices. The two areas play an essential role in controlling or managing cognition and attention. A couple of previous studies have found that students who are exposed to higher correlated colour temperatures have an advantage in cognition and attention, making fewer errors (Motamedzadeh et al., 2017; Hartstein, LeBourgeois & Berthier, 2018).

Though previously mentioned research has emphasized that light elicits several alerting and physiological reactions in human beings, the magnitude of such responses increasingly depends on other important factors.
Cajochen and colleagues (2005) indicated that intensity, timing, and duration of exposure to light significantly impact alertness, thermo-physiological responses, and even the heart rate. What was more surprising is that even the wavelength at which the light source exists can have a major impact on those measures. In the current study, the researcher adopted two of these measures to assess their impact: the brightness and the colour temperature.

The intensity of indoor lighting is distinct from its colour temperature. Colour temperature, measured in Kelvin (K), refers to the hue of light rather than its intensity (Morrice et al., 2021). The critical review of related literature revealed that one of the methods used to elicit biological reactions relating to the body sensation of daytime is simulating the characteristics of the sunlight. Krüger et. Al. (2018) conducted a study to understand the impact of daylighting features on human preferences. It was found that the relationship between daylighting features and human preferences is complex and can be affected by factors such as the time of day. Subjective votes demonstrated a correlation between the daylight evaluation previously performed by computer simulations and the results indicated a seasonal influence of daylight availability on lighting preferences. Consequently, Krüger suggested that it is essential to be aware of the potential impacts of daylighting on people and to consider the influence of these factors when designing and evaluating buildings. Hence, the effect of natural or simulated daylight should be considered to create spaces that provide comfortable and satisfying lighting conditions for their occupants. Consequently, it is expected that the body exhibits a higher level of alertness and generally more positive cognitive outcomes. Moreover, Galetzka et al.'s (2012) research found that keeping the lighting conditions similar to natural light, like daylight or sunlight, can help improve students' focus. Natural light has a high Colour Rendering Index (CRI), which is the index that assigns to the light source to display the object's colours as close to natural daylight. Thus, if good reproduction of natural light is to be achieved, one should be aware of both CCT and CRI that impact light quality for visual comfort and cognitive performance.

The results of the study showed that students who had optimal lighting while learning had more positive outcomes than those with sub-optimal lighting. This shows that the lighting conditions have an impact on focus and can help students understand their lessons better and be more successful in their learning.

1. Research Motivation

Lighting is an important factor in the learning environment, as its quality and characteristics affect both alertness and academic performance. While previous studies have focused on the effect of colour temperature on alertness and productivity, few have looked at its effects on students' reading speed and comprehension. Therefore, the researcher will critically review various studies to explore the effect of colour temperature on students' alertness, reading speed, and comprehension. Afterwards, the researcher will investigate how a dynamic light system could impact reading speed, alertness, and reading comprehension. Finally, the researcher will present the implications of these results in the classroom.

Several studies have previously pointed to CCT having an impact on students' performance and behaviour. As a result, numerous learning facilities in emerging and well-developed countries have adopted fluorescent lighting to provide their pupils with quality and energy-efficient lighting. Yet, LED lamps with higher CCT are more popular in educational institutions (Marrow, 2018). Be that as it may, there is not much known regarding the effect of light colour temperature on attention and wakefulness in reading speed and understanding of students. Consequently, this research will evaluate the effects of illumination on students' cognition, attention, reading speed and understanding, both beneficially and detrimentally. Generally, the primary incentive for doing the present research is that there are few data in the present literature dealing with the effects of light colour temperature on cognition and wakefulness in students' reading speed and understanding. The effects of lighting on the conduct and sentiments of students have been examined and noted. Morrow (2018) examined the association between lighting, investment, concentration, and focused behaviour. Specifically, Morrow (2018) contrasted that the two CCTs, 5000K and 6500K, were favoured by the instructors, dependent on how affirmative the understudies' reactions were as far as their engagement and concentration. Morrow (2018) found that when asked to select between 5000K and 6500 K-lit classrooms, the 6500K lighting was the preferred choice for 54.79% of the respondents, while the 5000K classroom was chosen by 38.36% of the respondents. This suggests that students are more attentive and participative under 6500K lighting. However, it is important to note that the effects of brightness on alertness are subject to the law of diminishing returns. Setting the brightness level too high, beyond the 6500K threshold, can be detrimental to the students' learning environment as excessively high Kelvin ratings can lead to distraction.

Yu and Akita (2023) conducted a study to determine the optimal colour temperature and desk illumination for workstations provided with general lighting whilst performing tasks involving paper and electronic devices. A seven-point Likert scale was used to assess subjective evaluation, while near-infrared spectroscopy (NIRS) was used to assess physiological parameters. The results showed that 1000 lux was the ideal level of illuminance for work on paper and computers, while 5000 Kelvin was the optimal correlated colour temperature (CCT). Furthermore, the study revealed that work performance was independent of devices or lighting conditions. Therefore, the findings of this study might yield recommendations for designing a lighting environment that provides psychological and physiological comfort when working with computers and paper devices.

The previous review of existing research highlights the scarcity of data in the relevant literature. While much of the available research has been devoted to exploring the consequences of CCT on well-being, performance, and mood, only a few studies have shed light on the implications of CCT on alertness and cognition. Thus, the present study hopes to fill this gap by examining the effects of attention and cognition of CCT.

The influence of interior environmental conditions on performance, contentment, and physical health has been the preoccupation of numerous scholars for a long time. It is well-documented that light can have both psychological and physiological repercussions on living creatures, including humans. Moreover, people's lighting preferences are evolving continually.

In terms of interior environmental conditions, one of the major concerns with interior lighting is the level of intensity and colour temperature. There is an ongoing debate about what type of lighting is best for workplaces and homes, with proponents of different types claiming to have scientific proof that their method is best. While a certain amount of debate is healthy in science, it is important to realize that there is no solid scientific evidence supporting one type of lighting over another, and the arguments put forward by advocates of different lighting methods often reflect personal preferences rather than objective facts. Several studies have investigated the effects of different types of indoor lighting on workers' productivity and mood. The "Brighter Workplace" program (Shaw, 2021), a joint initiative between Philips Lighting and LUX, has carried out research into the effect of light intensity on office workers' performance and productivity. One study found that increasing the lighting in an office from 300 to 600 lux resulted in significant improvements in both performance and mood among the workers. The study also found that the lighting level did not have to be increased to 600 lux (Wojcik, 2012), but levels between 500 and 600 lux also led to improvements. Similar results were found in another study that examined the effect of increased lighting intensity on office workers' mood and productivity. However, other studies have found no improvement in either productivity or mood following an increase in lighting intensity. A review article summarizing the results of several studies concluded that increasing the intensity of light does not increase workers' productivity or well-being unless it is done gradually over several weeks.

2. Purpose of the Study

The present study aims to explore the impact of five different levels of CCT (measured at 2,500K, 3,000K, 4000K, 5,000K, and 6,500K) on students' academic performance, as depicted by: the level of wakefulness, reading speed, and comprehension.

3. Research Question

The following main research question will guide the present study:

> What are the impacts of different light colour temperatures on students' cognitive functions and alertness, particularly in terms of reading speed and comprehension?

4. Research Limitations

This research approach adopted in this study has some drawbacks. Because of human error, the results of the study can be subjective. Additionally, the method may be time-intensive and potentially generate unrealistic scenarios. Moreover, the methodology utilized in the study can lead to results that are less applicable to real-life settings.

5. Thesis Structure

This thesis is organised into an introduction, literature review, theoretical framework, methodology, research findings, discussion, and conclusion. The introduction chapter will present the background of the study, the problem statement, the purpose of the study, research aims and questions, research motivations, and sensing a gap. While the literature review chapter will review, synthesize, critique, and emulate existing studies regarding the implications of light colour temperature on cognition and alertness in students' reading speed and comprehension. Following the literature review, the research methodology will be discussed to reveal the methodological framework of this study. The research findings chapter will present the findings of the experiments conducted in the study, including the demographic information of the research participants and the statistical data results. The discussion chapter will examine the findings of the current study considering the previous literature. Finally, the conclusion section will provide a summary of the main findings' discussion, suggestions for future research, and the pedagogical implications of the findings.

IV. Literature Review

Light provides the stimulus needed for humans and animals to visualise the world around them. Vision allows humans to meaningfully comprehend the world around them and act accordingly to what they perceive visually. Therefore, variations in light patterns, intensity, illuminance, and temperature are areas worth studying to understand human behaviour. This chapter introduces the lighting technology evolution, followed by how humans respond to light, the impact of light on humans' performance, and the influence of light in educational settings.

1. Evolution of Lighting Technology

In order to escape the threats of the dark and improve their vision even after the sun had gone down, humans have been attempting to master sources of lighting for thousands of years. There have been several advances in the field of lighting that has allowed humans to improve their vision in darkness in many ways, over these thousands of years. This section explores the evolution of lighting technology by dividing it by sources of light including natural light, incandescent light, florescent light, LED lighting.

1.1 Natural Light

In the history of mankind, humans have relied on sunlight and moonlight to assign activities to do in the morning or at night. Light is responsible for a range of bodily functions such as enabling and regulating visual performance, regulating alertness and sleep, altering mood, enabling cognitive functions, and secretion of hormones such as cortisol and melatonin. Consequently, humans were able to develop a healthy pattern of activity and assign time to rest (Mott et al., 2012).

This is why humans have developed an internal clock that is in line with the 24-hour cycle of the day (Czeisler, 1999) regulated by the changes in the availability of natural light throughout the day. Evidence for an internal clock is present through plenty of research (Sanabria, 2020; Touitou et al., 2017; Wearden, 1991). The existence of an internal clock and its alignment with the 24-hour changes in natural light is manifested in the existence of circadian rhythms.

In their review article, Touitou and colleagues (2017) have defined the circadian rhythms as:

> "…endogenous rhythms with a periodicity of approximately 24 h (24 ± 4 h). They are widespread and regulate most, if not all, of the major physiological systems in mammals… Circadian rhythms are dependent on an internal clock located in the suprachiasmatic nucleus (SCN) of the anterior hypothalamus. Each of the paired suprachiasmatic nuclei is composed of a heterogeneous group of about 10,000 interconnected neurons that give rise to circadian rhythms through specific neuronal gene expression patterns and by the rate at which they fire action potentials" (p.95)

The previous definition indicates that natural light is a significant factor that influences the biological functions not only of humans but also of all mammals. Natural light has many advantages that can not be neglected, such as:

1. Creating natural rhythm in biological systems thanks to ultraviolet rays.
2. The use of daylight in designing spaces leads is effective for eye health and reduces anxiety.
3. Improving individual performance in the workplace (Javadnia, 2016).

A study conducted by Xu et al. (2023) aimed to examine the relationship between high light levels and the timing of light exposure in classrooms with the sleep, alertness, and mood among Chinese high school students. High light levels were found to have a significant positive effect on acute alertness but did not significantly affect sleep or mood. On the other hand, the timing of light exposure was found to exert a significant effect on sleep and negative mood, with the morning condition being significantly associated with longer deep sleep duration, easier falling asleep, and lower negative mood. Despite the inability to fully accept the hypothesis, this study was the first to directly correlate high light conditions and timing of light exposure with subjective and objective sleep, alertness, and mood of Chinese high school students and can serve

as a reference for the implementation of healthy lighting in classrooms. The study showed that high light levels in the morning or evening boosted alertness compared to regular lighting, but there was no significant difference in sleep or mood. High levels of light in the morning increased sleep quality and reduced negative mood among boarding high school students. The findings imply that adequate lighting conditions and light exposure timing can improve students' sleep quality, alertness, and mood.
Consequently, natural light and its optimal use became an integral part of architectural development. Old architecture always put great consideration towards harnessing natural light so that humans could reap the benefits of the natural sources of light as much as they could. The environmental conditions and latitudes were different across the world. As a result, the considerations for natural light were different for the architecture of their times. Giucastro (2019) studied how different cultures incorporated natural light differently all over the world. They noted that "In a mild climate in winter and hot in summer, design choices are intended to maximize thermal input and disperse it to a minimum in winter, while shielding is needed to provide better environmental comfort in the summer" (p. 64). This shows that light has been a consideration in architecture for a long time, depending upon the environmental conditions and climate of the place. Natural light is often used as an inspired theme in architectural design (Dębowska, 2017).

Currently, natural light is still considered an integral design element from a sustainable view with the goal of energy conservation in mind through the intelligent use of daylighting design. If natural light is incorporated into the architecture of a building effectively, the use of artificial dynamic lighting and the energy cost for the building must be reduced significantly (Philips, 2004). Following is an example of using architectural design to ensure that the indoors get enough light (Yale, 2018):

Figure 1 - Natural Lighting Indoors (Generated by Midjourney)

The world is largely still run-on fossil fuels and saving energy means less consumption of fossil fuels which may lead to better environmental outcomes. Mohammid Tabar et al. (2019) noted that there are numerous ways through which architecture can make optimal use of natural light in order to increase energy savings. The factors that can affect the illuminance of the material of floor coverings, wall coverings, ceiling coverings, window positioning, and colour changes in the interior. Thus, a lot of work is still needed to explore how natural light can be incorporated into the interior architecture.

1.2 Light Emitting Diode (LED) Lighting

Figure 2 - Modern Light Emitting Diodes (LEDs) come in different colours (Generated by Midjourney)

Light Emitting Diode (LED) lighting is an important part of today's lighting systems. The market for LED is huge and growing (Zheludev, 2007). The inventor of LED was a Russian researcher named Oleg Vladimirovich Losev who had a short research career but was successful in getting 16 patents (Zheludev, 2007). Losev was way ahead of his time when he predicted the potential of LED for telecommunication. He thought that LED would end up bringing a revolution in telecommunications. He wrote the following in the introduction of his patent in 1927:

> "The proposed invention uses the known phenomenon of luminescence of a carborundum detector and consists of the use of such a detector in an optical relay for the purpose of fast telegraphic and telephone communication, transmission of images and other applications when a light luminescence contact point is used as the light source connected directly to a circuit of modulated current." (Zheludev, 2007, p. 191)

This should have been the beginning of a revolution in photonic telecommunications but following his death, his work was mostly forgotten in this area.

The most popular LED lighting systems today involve white LED bulbs. As the name suggests, white LED bulbs emit white light. There are two approaches to making a white LED bulb: a multi-LED chip and an ultraviolet (UV) LED child. A first approach is a multi-LED-chip approach in which the light emitted from three LED chips emitting the three primary colours (red, green, and blue) are mixed to generate white light. A typical multi-LED bulb is illustrated in Figures 3 and 4 below:

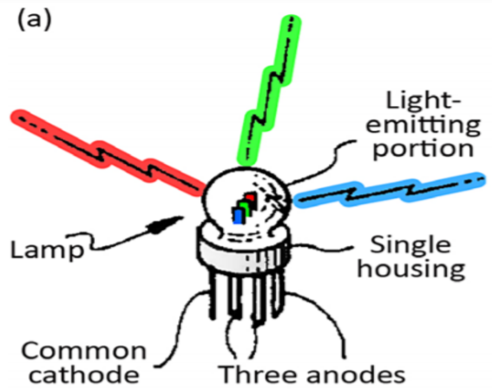

Figure 3 - Perspective View of multi-LED Chip Alarcón Correa (2020, p.6)

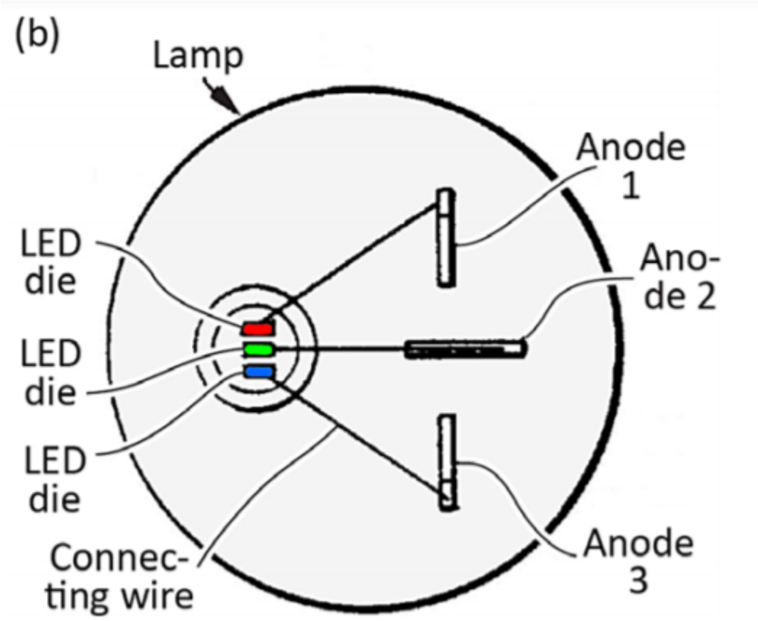

Figure 4 - Top View of Multi LED Chip (Cho et al., 2017, p.2)

The second approach through which white LED light is generated is based on ultraviolet (UV) or violet LED chips. It has a phosphor that ends up absorbing UV or violet light and ends up converting it into broadband white light. This can be seen in Figure 5 below:

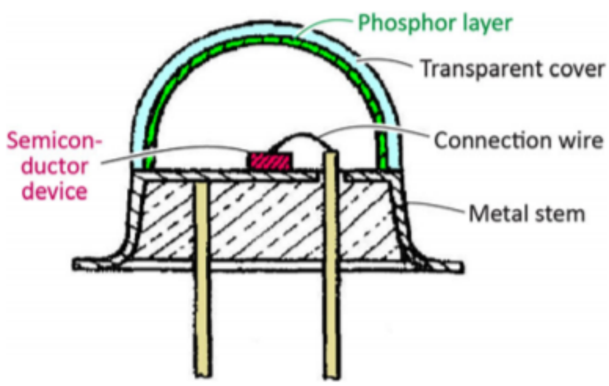

Figure 5 - UV or Violet based white LED Light system (Cho et al., 2017, p.2)

1.3 Colour and Spectral Properties of Light

Visible light is the electromagnetic radiation that humans can detect. Humans can see only a part of the whole electromagnetic spectrum. This spectrum ranges from high-energy gamma rays that have very small wavelengths of less than 1 x 10^{-11} cm to radio waves that are low in energy and have wavelengths that can be measured in meters. The following Figure 6 shows the electromagnetic spectrum (The Editors of Encyclopaedia Britannica, 2015):

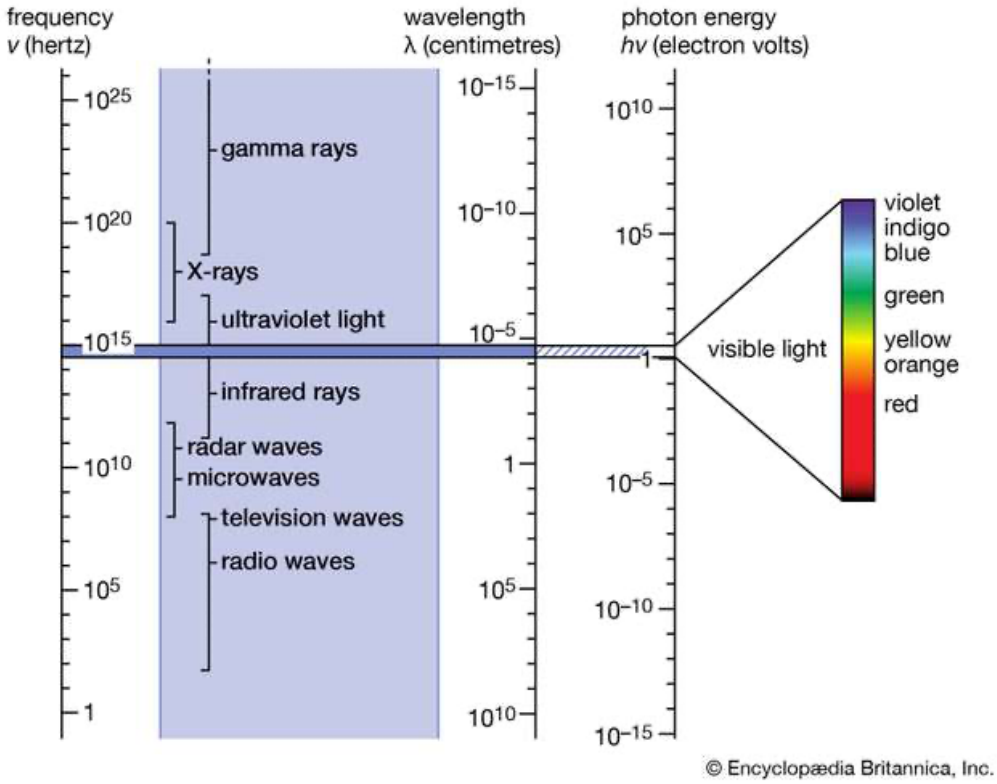

Figure 6 - Electromagnetic Spectrum Britannica, T. Editors of Encyclopaedia (2022).

The previous figure reveals that the human eye could detect a small part of the electromagnetic spectrum called "visible light". The wavelengths separate into the colours of the rainbow as every colour is a different wavelength. Thus, the various wavelengths are perceived as different coloured light by the human eye.

> "The entire electromagnetic spectrum, from the lowest to the highest frequency (longest to shortest wavelength), includes all radio waves (e.g., commercial radio and television, microwaves, radar), infrared radiation, visible light, ultraviolet

radiation, X-rays, and gamma rays. Nearly all frequencies and wavelengths of electromagnetic radiation can be used for spectroscopy.” (The Encyclopaedia Britannica, 2015)

2. Light and Performance

Findings from different studies examining the effect of light on human performance will be presented in this section. It will focus on how light has a significant impact on the circadian rhythm and how the convenient lighting system in various workspaces can boost productivity, concentration, and occupational safety. It will also explain how changing the colour temperature of the light during the day can help to match a person's biorhythm and improve their performance. These different aspects of illumination can help people reach their highest potential in any working or learning environment.

2.1 Circadian Rhythm

Before the discovery of electricity, people used low-power lighting devices based on flammable substances - candles, oil lamps, and similar devices, which did not provide enough light for work and active wakefulness at night. Nowadays, it is easy to turn on a fluorescent lamp of any power, to provide working conditions at any time of the day either for individual work or for a whole enterprise (Veitch and McColl, 2001). However, the amount of light entering the body during the day unambiguously affects the activity and quality of sleep. Let's take a closer look at the effect of light on a person (Veitch and McColl, 2001).

Scholars have nearly reached common ground on the definition of the circadian cycle, which is a "change in bioprocesses in the body during the day." (Srour et al., 2018; Farhud & Aryan 2018; Korman et al. 2020; Koritala et al., 2021). The cycle takes in all stretches of everyday life - rest, active alertness, fruitful parts, weariness, rest, and so forth. These phases shift because of the effect on the body of the hormones it produces - dopamine, cortisol, melatonin, and numerous others. (Mills et al., 2007). Any change in the level of these hormones leads to a change in biological rhythms.

The healthy performance of the circadian cycle has many benefits, such as having enough sleep, showing high indicators of efficiency, being more active, having good health, and enhancing mood (Rea et al., 2002).

Oh et al. (2015) demonstrated that the conventional figures of merit for smartphone displays are insufficient when assessing the health effects of individual smartphone displays for use at night-time. The newly developed figures of merit for circadian luminous efficacy of radiation (CER) and circadian illuminance (CIL) related to human health and circadian rhythm were measured and compared to analyse three commercial smartphone displays. The CIL and melatonin suppression values (MSVs) of SNS messenger screens for all three displays were higher than 41.3 blx and 7.3% in a dark room at night, respectively. As Oh, J. et al. stated “This CIL level for smartphone displays can significantly decrease melatonin secretion and thereby affect human health and circadian rhythm”. Therefore, it is important to consider the CER and CIL values when evaluating the health effects of smartphone displays for night-time use. Additionally, a method of decreasing the emitting wavelength of blue LEDs in a smartphone LCD backlight was proposed, which could potentially reduce the circadian effect of the display. Ultimately, it is important to use smartphones at the proper brightness setting in a dark room to avoid circadian cycle disruption risk associated with blue light exposure and inappropriate interior lighting.

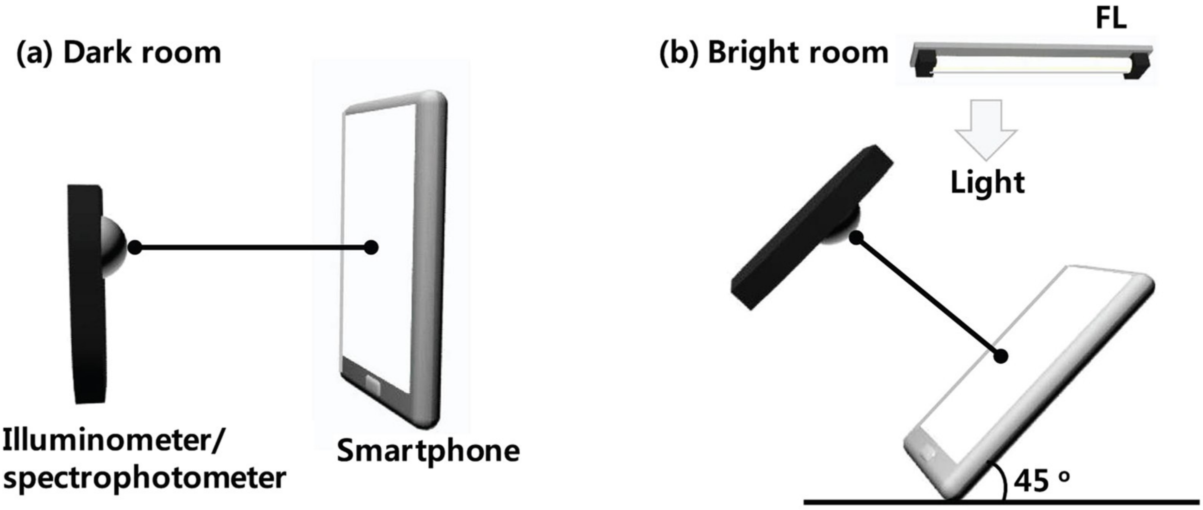

Figure 7 – The use of smartphones at the proper brightness (Oh et al., 2015, p. 2)

If the cycle is disrupted, the individual suffers from insomnia, the hormonal secretion is disturbed, and increasing signs of stress appear - fatigue, lack of sleep, nervousness, and irritability (Hoffman et al., 2008).

2.2 Effects of daylight on circadian cycles

Light directly affects the production of hormones, physical, and cognitive activity, and quality of sleep, which is why one should observe the regime of not only nutrition but also lighting, trying to bring it as close as possible to the natural change of day and night (Rea et al., 2002).

Artificially prolonging the working hours throughout the day with the help of lighting devices, a person increases the length of the working day, but significantly reduces the quality of sleep and rest (Hoffman et al., 2008).

If light can disturb the circadian cycles, then it can be used to harmonize them, using the latest scientific developments.

2.3 Controlling biorhythms with office lighting

Akerstedt and Gillberg (1990) indicated that the control of the temperature of light enables the formation of biorhythms naturally, even in conditions of prolonged work. To adjust the biorhythms of office workers to the daily routine, you should use light sources with different temperatures for each period. During periods of greatest activity, when full dedication is required from employees, it is important to turn on a cold light - it makes employees collected, attentive, and more alert, and speeds up the brain (van Bommel and van den Beld, 2004). To solve standard tasks that do not require increased attention, and alertness, using lamps of a neutral spectrum is suitable. While during periods of rest, lunch break, for example, it is important to use warm light that promotes relaxation (van Bommel and van den Beld, 2004).

In addition, warm light (up to 3.5 thousand K) relaxes the body and prepares for a period of rest, which can be used in the fight against insomnia (Aries, 2005). Lamps with such characteristics are good for placing in the bedroom and recreation room. The neutral part of the light spectrum is suitable for performing everyday tasks in a calm rhythm, it does not reduce performance, but it also does not give such a boost of vivacity as cold tones (Aries, 2005).

Thus, with the adjustment of the lighting system at home and the workplace, you can put in order not only your biorhythms but also get rid of the associated problems with appetite, sleep, and excess weight, increase stress resistance and normalize hormones (Aries, 2005).

2.4 Lamp colour rendering

The colour rendering of the lamp determines how adequate the colours will appear in the room. Low colour rendering lamps distort colour perception, which also affects performance (Feynman & Zee, 2014). The index of this parameter is commercially labelled Colour Rendering Index (CRI), which is the performance of light sources compared to a reference source for various visual tasks. The higher the index, the more natural the colours appear in the room. Incandescent and halogen lamps have the highest colour rendering. Nevertheless, - fluorescent lamps with a five-component phosphor, MGL (metal halide) lamps, and modern LED lamps have good colour rendering (Lechner, 2015).

2.5 The best lighting is natural

Natural sunlight improves mood, concentration, and productivity, and decreases depression. Hence, the design of workplaces should help the workers to benefit from the sunlight hours. It is recommended to arrange tables on the left side of the window: this setting will make more light penetrate the room, and the workers' eyes will not get tired (Lechner, 2015).

Contrary, the complete lack of access to natural light leads to negative consequences. According to a study by Hoffman et al. (2008), employees working in workplaces without windows sleep on average 46 minutes less than those working in offices with windows. Lack of sleep and disturbed circadian rhythms lead to decreased productivity.

2.6 Lighting for productive work

Though access to sunlight might be limited for many reasons in the workplace, it should be replaced by convenient artificial lighting. The lighting should be close to neutral white with a temperature of 4,500-5,000 K. Just like the midday sun, it increases concentration and relieves fatigue (Lechner, 2015). Also, the light should be evenly distributed over the entire working area and fall exactly from above. Otherwise, it will create shadows or blind the eyes, which will reduce performance. It is better not to use a table lamp without general ceiling lighting, as harsh light contrasts tire the eyes (Lechner, 2015).

2.7 Lighting for negotiations and meetings

Born and wolf (1999) revealed that using warm lights in the workplace is very beneficial in certain situations. Very warm lighting, less than 3,500 K, is placed in meeting rooms and recreation areas. It evokes a sense of comfort, relaxes, and sets up confidence. Therefore, yellow warm lighting is used in conference rooms as it simultaneously maintains a working mood and relaxes

Furthermore, this type of lighting is used in living rooms, bedrooms, and over the dining table to create a cozy atmosphere at home (Born & Wolf, 1999). However, one won't be able to work productively under such lighting - one might feel sleepy. In addition, too dim light increases eye strain and can provoke headaches (Born & Wolf, 1999).

2.8 Change in colour temperature throughout the day

Working in cold light throughout the day is tiring and leads to decreased performance and disruption of circadian rhythms. Therefore, as fatigue builds up, it is better to move to relaxing areas with warm lighting or use dimmers to reduce the light intensity (Rea et al., 2002). This does not account for seasonal variations, which affect natural light exposure. During winter, when daylight is limited but in summer, the extended daylight hours for example could delay the onset of sleep.

Also, it is recommended to switch the colour temperature of gadgets in the evening to "Night mode". This adjustment will relax your eyes and help your body prepare for sleep. To do this, install a blue light-blocking app or search for "Night mode" in the settings. (Lechner, 2015).

2.9 People in the Workplace

It is very important to provide employees with comfortable working conditions, among which high-quality lighting is a must. The efficiency of the employee's work performance, mood, and safety depend on it (Lechner, 2015).

Lighting in the work area serves many purposes such as:

- Provide optimal working conditions following standards and requirements.
- Reduce the fatigue of the organs of vision.
- Ensure the safety of employees.
- Prevention of occupational diseases.
- Improving labour efficiency and quality of work (Lechner, 2015).

To achieve the previously mentioned purposes, the lighting system at the enterprise must meet the following requirements:

- High-quality illumination of the working area, which complies with the current sanitary standards. Uneven illumination forces the eyes to adapt to different brightness of surrounding objects, which leads to rapid eye fatigue.
- Optimal brightness. For a person's vision, both dim light and too bright light are equally harmful. This manifests itself in cramps in the eyes, frequent headaches, and visual disturbances. Therefore, it is necessary to correctly calculate and design lighting to obtain a comfortable brightness in the room.
- Adequate contrast is responsible for the visibility of objects and affects visual performance.
- The absence of glare, as their presence contributes to rapid eye fatigue and increases the risk of injury at work.

- Correctly selected colour temperature depending on the functional characteristics of the room.

2.10 The effect of lighting on vision and human health

Almost 90% of the information we receive is through the organs of vision. Unsatisfactory illumination in the room and pulsation of lamps that are invisible to the naked eye, after a few years can lead to various diseases of the organs of vision and deterioration in mental health (Hoffman et al., 2008). Not only our eyesight, but the entire human body reacts sharply to uncomfortable light. This manifests itself in fatigue, drowsiness, frequent headaches, and increased blood pressure, and as a result, performance decreases (Hoffman et al., 2008).

Too high brightness also negatively affects the body, contributing to a decrease in vision. To conclude, comfortable light has a tonic effect on a person, promotes a good mood, and improves the functioning of the nervous system. It is recommended to use high-quality LED lighting, which will cause neither physical nor psychological negative consequences (Aries, 2005).

2.11 How lighting impacts performance

According to Lecher (2015) and Huang et al. (2015), there are significant effects of lighting on safety and labour productivity, such as:

• Intelligent design of the lighting system for office premises contributes to effective work, attentiveness, and composure of staff and an increase in efficiency by up to 32%.

• The improvement in illumination at a manufacturing enterprise led to a significant increase in productivity, and quality of work.

• According to the statistics of accidents at workplaces, where the lighting system is correctly selected, there are two times fewer accidents.

• Using an optimal light system reduced 30%of flaws in performance.

• High-quality lighting in classrooms has a positive effect on pupils and students, they more easily perceive the educational material, with less effort (Huang et al., 2015).

In any room, lighting should be optimal, which combines good luminous flux, high quality, efficiency, and safety. The following table summarises the effects of each lighting on performance and safety according to Lecher (2015)

Type of Lamp	**Impact on Man**
Incandescent Lamp	Most countries have long abandoned such lamps. They are not only harmful to human health, because they have a high coefficient of ripple level, low luminous efficacy, and a small colour range, but also pose a fire hazard.
Fluorescent Lamp	• Such lamps contain mercury, so they can be a danger to human health. •White light - suppresses the production of melatonin in the human body, which in turn leads to a decrease in immunity, disruption of the biological clock, and the functioning of the nervous system. • flickering is invisible to the human eye and the stroboscopic effect has an extremely negative effect on the nervous system, causes fatigue and poor health, and significantly reduces the ability to work. • Harmful UV radiation aggravates skin problems, causing premature ageing and cancer.
Halogen	Iodine cycle incandescent bulbs seem to be less hazardous to health. Their emission spectrum is closer to natural light, which is good for vision. Though, a large drawback is the pulsation of the light flux, which can lead to the appearance of a stroboscopic effect. This can have negative consequences in manufacturing enterprises (increased injuries and increased flaws in performance).
LED	LEDs are one of the safest luminaires available today. They do not contain materials hazardous to health, strong, economical and durable (service life is up to 10 years). LED luminaires increase employee productivity by more than 30% compared to other types. Although the price of LED lamps is relatively high, the positive impact of LED lighting justifies its pricing.

Table1 - Type of Lamp and Impact on Man

2.12 Influence of lighting on occupational safety

Most accidents at factories occur due to neglecting the optimal lighting standards. Poor lighting leads to an increased number of work injuries, decrease the efficiency of equipment maintenance, and decreases productivity and quality of work. Therefore, high-quality light is the key to safe work. It increases the ability to work and reduces the risk of injury in the workplace.

2.13 Colour Temperatures and how they are Measured

There are different methods of describing colour temperature. In this case however, the spectral power distribution (SPD) diagram represents best the major features of the light source. SPD is actually the “fingerprint” of light, which describes energy output along different wavelengths in the electromagnetic spectrum. Regardless of this, the averaged CCT is widely considered as a simple representative of the look of the light. There has already been investigation in the area of the influence Golasi et al. (2019) had on light emitting diode (LED) technology, the most common lighting system at the time of this investigation. LED bulbs and light fixtures are long lasting and reliable, with the colour temperature and energy uses being quite efficient.

One of the least understood aspects of choosing a colour for space lighting purposes by consumers is colour temperatures. A colour’s temperature is measured using Kelvin (K) unit. A cool white light, for example, often ranges from 3000K and 5000K, depending on the actual specifications and design elements of the light bulb or fixture. A warm light sits somewhere between 2700K and 3000K in the colour temperature spectrum. Daylight, on the other hand, sits anywhere from 5000K to 6000K.

Terms like warm, neutral, cool (and even cold) provide a subjective impression of light but do not encompass its complexity. Light colours are also often associated with cool colour temperatures, so the researcher used the terms light and cool interchangeably, which is in line with nomenclature norms established by researchers in studies such as Baniya, R. R. et al. (2018), Golasi et al. (2019), and Brambilla et al. (2020).

Hence, colour temperature is one of the most accurate ways to describe the appearance of the light that is being emitted by a light bulb, or in the case of LED bulbs, diodes. The lowest colour temperature lights often start from 10000 K. These are lights that may often be described in the literature as light, cool, or cold.

The highest colour temperature lights end at 1000 Kelvin. Light bulbs that have a colour temperature rating of 2000 Kelvin, for example, can be accurately described as a warm temperature lighting fixture, because their colour temperature rating sits nearer to the maximum end of the warm spectrum of 1000K. These, however, are ratings that exist at both ends of the colour temperature spectrum ranging from coldest to the warmest. In typical commercial, residential, and industrial lighting applications, the colour temperature rating usually falls anywhere between 2000K and 6500K.

Color Temperature (KELVIN)	**2700K**	**3000K**	**5000K**
Light Appearance	Warm White	Warm White	Cool Daylight
Ambience	Cozy, inviting	Warm, welcoming	Crisp, invigorating
Best for	Living rooms, kitchens, bedrooms	Bathrooms, entryways, outdoor	Basements, garages
	Table/floor lamps, pendants, chandeliers	Vanities, overhead lighting	Task lighting, security lighting

Table 2 - Colour Temperature Measurements

Table 2 illustrates a typical light colour temperature range, from the warmest to the coldest (Ru et al., 2019). As the colour temperature decreases in Kelvin, the colour temperature gets warmer. At the other end of the colour temperature spectrum are fixtures with a high Kelvin rating which tend to have a lighter or cooler colour temperature.

Ru et al. (2019) sought to determine the non-image forming effects of lighting and correlated colour temperature in the office on the employees' mood, alertness, and performance across various cognitive domains. 57 healthy individuals were tested in a simulated office environment, with responses assessed based on their subjective feedback about the impacts of the different lighting settings (illuminance level and colour temperature) on mood, alertness, and cognitive performance. Ru noted a slight degree of inconsistency in the tendency of colour temperature to have either a positive or negative influence on performance. They also found that the performance of some office employees was unchanged despite the use of different colour temperature settings. This leads to the question (what exact luminance settings (in terms of colour temperature) lead to an increase or a decrease in performance?). Ru et al. (2019) have also observed that higher light-correlated colour temperatures elicited no significant benefits on alertness or performance. A possible explanation for these results is that their quasi-experimental settings were designed to be implemented during the daytime. The lighting conditions during the day may have already been optimized, or at least near-optimum levels, due to the high level of brightness and colour temperature.

Bellia et al. (2013) conducted a study to investigate the effects of daylight and electric light on occupants to provide better lighting and promote wellbeing. The results showed that the spectral power distribution (i.e., graph or function that shows how the power of light is distributed across different wavelengths. It essentially depicts the "fingerprint" of a light source, revealing the amount of energy it emits at various wavelengths within the electromagnetic spectrum) that reaches the eyes is influenced by the indoor and outdoor reflectance and the Correlated Colour Temperature (CCT) values detected at the eyes are always between 4000 K and 6000 K. Additionally, the percentage of visual field occupied by windows, sky, internal, and external surfaces showed that most of the light reaching the eyes comes from the internal surfaces. These findings suggest that lighting design can have an effect on occupants and should be taken into consideration when designing educational environments. This study emphasizes the importance of understanding the non-visual effects of light on human health and performance.

Morrow (2018) conducted a study that also featured an experimental approach where she examined the impact of lighting on student attitudes and behaviours in the classroom. One of the interesting parts of Morrow's (2018) study was her discussion of the relationship between lighting, engagement, attention, and on-task behaviour. She examined which the of two levels of colour temperature, 5000K and 6500K, were preferred by the teachers, based on how positive the students' responses were in terms of their engagement and attention. The results revealed that the 6500K lighting was perceived as best for focusing during testing by 54.79% of respondents, while the 5000K classroom was selected by only 38.36%. What this means is that more educators selected the 6500K colour temperature in Morrow's (2018) study, based on the simple observation that their respective students seemed more attentive and participative under such conditions. The results in Morrow's (2018) study does not coincide with that of the present study, at least when it comes to the optimal level of lighting brightness. The threshold appears to be much higher (at 6500K) in Morrow's (2018) study than that in the present study, at only 5000K.

Ru et al. (2019) examined the non-image-forming effects of illuminance and correlated colour temperature on outcomes such as mood, alertness, and cognition. Ru et al. (2019) found that exposure to high and low levels of illuminance (brightness) did have a significant impact on the alertness and other measures of cognitive performance of the participants. In terms of the correlation between light colour temperature and alertness, these results contradict those of the present study because Ru et al (2019) concluded that higher correlated light colour temperature did not elicit any significant benefits on alertness or performance. Ru et al. (2019) suggested that the light colour temperature does not matter so long as there is sufficient brightness in the room. One potential reason for this contradiction might be that they conducted their study in an office setting.

Another study conducted by Yasukouchi et al. (2019) examined the non-visual effects of lights regarding cortical arousal levels, autonomic nervous activity, and nocturnal melatonin secretion; and examined work productivity and subjective responses during diurnal exposure to artificial skylights and conventional fluorescent lights in a simulated office environment.

The researchers assessed Autonomic Nervous Activity, Alpha Wave Ratio, Contingent Negative Variation, work performance, and subjective responses during daytime exposure to either an artificial skylight or fluorescent lights for 10 male participants.
The results showed the use of artificial skylights more than conventional fluorescent lights within the simulated office environment.
The results suggested that individuals under artificial skylights would have the same work performance as those under fluorescent lights with less excessive tension of arousal level. In other words, the researchers suggest that artificial skylights that simulate natural sunlight and blue skies help to sustain work performance with lower psychological and physiological stress and indorse consistent long-term work productivity with comfort and good health from the point of view of increased nocturnal melatonin secretion and/or an advanced shift in circadian rhythms.

In a different context, Hawes et al (2012) studied the visual perceptual, affective, and cognitive implications of supplying temporary military shelters with either fluorescent or one of three LED lighting systems with different colour temperature and luminance. The study sample comprised twenty-four volunteers who were tested across five days. The findings of the study revealed that volunteers showed increased fatigue ratings with fluorescent compared to LED, and this effect was coupled with slower response times on tasks measuring spatial and verbal memory.

2.14 Consensus about Light and Performance

The current study focused on assessing the temperature of the colour of the light that is being emitted by a set of fixtures. The term performance in the current study refers to, an individual’s level of cognition and alertness which are measured by reading speed and level of comprehension.
Some studies have proven that lighting can have a significant effect on a person’s mood, health, well-being, and alertness. A dated study that was published in the 1970s, for example, revealed that the characteristics of lighting in a space can affect a person’s visual performance (Boyce, 1973).

Boyce (1973) observed a sample of 150 respondents as they perform four tasks, namely, self-paced Landolt ring charts, externally paced Landolt ring charts, conveyor inspection, and a tracker task. Changes in illumination were used as the external stimuli in the evaluation of the difference in performance results. Boyce’s (1973) study’s results revealed that differences in performance could be attributed to a higher level of illuminance in the room of the experimental group.

Those who stayed in the room where there was poor illuminance did not fare as well as the other group in most of the tasks. Now, there certainly are flaws in the way how Boyce (1973) conducted his quasi-experimental study, but his findings did serve as evidence that illuminance (or lighting) characteristics do have a significant influence on a person’s cognitive performance. Boyce’s (1973) study, while indeed dated, was one of the few studies that were published during that period about lighting and its impact on performance. After Boyce’s (1973) study was published, many researchers in the field of technology, manufacturing, engineering, and even education started to address the same topic more deeply and assess its relationship with various aspects of human performance.

As mentioned in Boyce (1973), the "flaws" can be outlined as the limitations of the design of the study, such as being quasi-experimental in nature that needed randomization making it susceptible to possible confounders impacting the internal validity of the study. Furthermore, the study relied on a small sample size of 150 participants which could restrict the scope of applicability of the conclusion made. To make the matters worse, even Boyce’s research was limited to a particular cluster of tasks and even ignored individual variations with respect to lighting responses.

In a more recent study, Sleegers et al. (2013) examined the effects of lighting on the student's level of concentration. Lighting conditions were predetermined using vertical illuminance levels of 350 lux and 1000 lux, which in terms of the more traditional Kelvin-based measurement, equates to 3000 and 12000K. In fact, it is a wrong claim to consider illuminance and correlated colour temperature as equivalent; these two factors are separate and quite different. Illuminance in lux is the measure of the extent of light arriving at a particular surface, whereas CCT is the measure of the colour of lightness in Kelvin from hot to cold temperature. These parameters do not equate and can have different effects on performance – illuminance determines the light and the picture clearness; while CCT has relevance in temperature regulating hampered feelings and the state of being active. Reckoning these variables and depictions together can lead to inaccuracy interpreting the role of lighting on cognition as it performs differently on different aspects of the work in relation to lighting.

Sleegers et al. (2013) used a sample of dutch elementary school children in their study. For the first two experiments, 89 pupils were observed from two different schools in Study 1; and 37 pupils were observed from two different classrooms in Study 2. In both studies, Sleegers et al. (2013) reported that a flexible and dynamic lighting system was used. In the third study, data were collected from 55 pupils who were in a simulated school environment in a windowless laboratory setting they concluded that lighting could have a positive influence on student concentration in the classroom. Dynamic lighting systems that can be adjusted to fit different learning activities and tasks have been shown to be particularly advantageous. These findings suggest that providing classrooms with optimal lighting conditions can be an important factor in improving student performance. It is essential for teachers, school administrators, and policy makers to be aware of the potential benefits of lighting for learning and to take the necessary steps to ensure that students receive the best possible lighting conditions in school.

Park et al. (2013) adopted a neurological methodology to demonstrate the effect of altering certain features of the brightness and colour temperature of lights on cognitive performance. The researchers aimed primarily to find a physiological explanation between lighting characteristics and cognitive performance. To achieve their purpose, they recruited thirty-two healthy volunteers to participate in the study.

The participants were tested under four different conditions according to colour temperature and brightness using a combination of two different types of colour temperature (2766 Kelvin and 5918 Kelvin), and also two different types of brightness (300 lux and 600 lux). They were asked to answer quickly and accurately questions from Raven's Standard Progressive Matrices and Raven's Advanced Progressive Matrices. Each light condition required 15 minutes. During the experiment, EEG measurements were taken from the scalp using a SynAmps2 DC amplifier and a

10/20-layout, 64-channel, Quik-cap electrode placement system. In addition, the participants answered an 11-point Likert scale to assess their valence and arousal in each light condition. The results of the Analysis of Variance (ANOVA) indicated that there was a significant effect of brightness on the valence (performance) scores. However, the arousal scores varied significantly by colour temperature. Higher arousal scores were recorded among the participants during periods of the tests when they were being exposed to cool colour temperatures this statistically significant result was supported by participants "subjects reported that they felt more pleasant in bright conditions and more relaxed in warm colour temperature conditions" (p.126).

Another study (Zhu, et al., 2019) aimed to examine the effects of lighting and correlated colour temperature. This study focused on the impact of light colour temperature on three specific aspects of performance, namely, cognitive performance, subjective mood, and level of alertness. The researchers used a sample consisting of 60 healthy individuals. In the analysis of their findings, Zhu et al. (2019) stated that the majority of their participants reported feeling less sleepy when they got to work in an environment with exposure to bright light. This result goes along with Park et al.'s (2013) finding in their study about the relationship between lighting brightness and its effect on alertness.

It could be the level of brightness colour elicited the negative response from the participants. This means that the two factors of brightness and colour have a relation in the lighting context and do not exist as separate factors, as Zhu et al. (2019) study probably thought that high brightness density with cool colour temperatures, blue or white light for instance, would be too much demand on mood even though colder lighting tends to increase cognitive performance. It follows that the light strength may therefore have been too high and so overstimulated the participants making them feel uncomfortable. On the related observation that the effect on long-term memory was "only in the afternoon," this result shows that the effect of lighting on cognitive performance is not constant throughout the day and is subject to variations due to alertness and mental energy levels over the course of the day. In the afternoon slump when cognitive performance is lower, lighting conditions that are expected to deliver results in relation to core processes may not work as well requiring time of day to be factored in when designing for lighting conditions that aid memory and cognitive functioning among learners. The results showed that the slowest responses in inhibition, working memory and facial expression recognition occurred at the low warm lighting; the effect on long-term memory was most pronounced at the high cool light exposure, but only in the afternoon for tasks requiring the recognition of neutral words; these results suggest that future research on good indoor lighting should consider illuminance levels and correlated colour temperature, as well as other variables, to optimise lighting effects during regular daytime hours.

3.15 Light and its Impacts on Reading Speed

Up to now, there has been a limited number of studies that inquired specifically on the impacts of lighting characteristics such as the light's colour temperature on cognitive processes involved in academic outcomes such as reading speed (Geerdinck, et al., 2009; Konstantzos, et al., 2020). Among the few studies that covered this topic, one was conducted by Morrice et al. (2021) to identify the optimal colour temperature and illumination characteristics that can be used to facilitate reading for visually impaired adults. They used a set of three reading devices, namely, the Lux IQ, the Apple iPad, and a smart bulb to assess the optimal colour and illumination characteristics that can influence reading outcomes (e.g., reading speed) among a group of young, old, and visually impaired adults. The participants were asked to read a standardized set of texts at baseline lighting conditions. Baseline lighting conditions were described as an environment with normal lighting, and no assistive device (e.g., auxiliary lighting).
The participants were then asked to do the same read a standardized set of texts, using the Apple iPad, the Lux IQ, and a smart bulb. Morrice et al. (2021) reported that lighting characteristics such as colour, condition, and brightness all led to significant changes in the participants' reading speed. The results of the regression analysis to revealed that 24% of the variance in reading speed can be attributed to the interplay of lighting conditions. In another study, Morrice et al. (2021, p. 1) demonstrated the importance of adjusting illumination and colour when it comes to reading. It showed that both younger and older adults read significantly faster at lower colour temperatures. Furthermore, luminance, colour temperature, and age were all significant predictors of reading speed. The findings also suggest that the LuxIQ, the Apple iPad, and the Smart bulb can be effective tools to assess optimal colour and illumination to facilitate reading in adults. It is important to consider the effects of colour

and illumination on reading, as they can significantly improve reading speed and comprehension.

Though Morrice et al.'s (2021) used multiple independent variables and tested how their effect on reading speed, it is better to conduct studies where the light colour temperature is isolated to determine its contribution to reading speed (Lewinski, 2015).

3.16 Light and its Impacts on Comprehension

Comprehension is a much more complex process than just reading speed, mood, alertness, and cognition (Woolley, 2011). Comprehension refers to the process of understanding. At some point, the variables that have been examined so far in this literature review might have a significant effect on comprehension (Wise, et al., 2007). Individuals might fail to achieve an appropriate level of comprehension if they are not in a good condition, do not have a suitable level of alertness or arousal; or if they face problems with their cognitive performance (Killgore, 2010).

Similarly, if the illumination conditions and characteristics can have a significant influence over even just one of such variables, then it would also be correct to suggest that illumination conditions and characteristics would also have a significant influence over a student's level of comprehension. Mott et al. (2012) examined the influence of dynamic lighting on student learning. According to Mott et al. (2012), the quality and characteristics of lighting substantially vary in nature, and even more so in controlled environments. This raises the question of what artificial light characteristics have the potential to influence comprehension, and to a greater extent, learning, the study has demonstrated the effectiveness of dynamic lighting systems in improving reading speed in younger and older adults, as well as those with visual impairments. The results suggest that lower colour temperatures and higher lux are better for reading speed and that younger adults tend to read faster than older adults. These findings support the notion that light quality can have a significant impact on learning, and that dynamic lighting systems can be beneficial in educational environments. As such, it is recommended that further research be conducted to explore the potential applications of dynamic lighting systems in other areas of learning.

While the present study's emphasis is light colour temperature, it is still worth noting that in the previously published studies about the effects of lighting characteristics on aspects of performance such as the actual colour of the light, the level of brightness, and the type of device and or technology that is being used to emit the light were found to have statistically significant impacts too, albeit at varying levels. There was a somewhat frequent pattern of results that point to the suggestion that light colour temperature is not the only artificial lighting characteristic that can influence performance (Hartstein, et al., 2018; Choi & Suk, 2016; Wolffsohn, et al., 2012; Weitbrecht, et al., 2015; Lin, et al., 2019).

In Mott et al.'s (2012) study, they used a sample population composed of 84 third grade students. They were asked to perform a series of academic tasks under two lighting conditions, namely, normal lighting, and controlled artificial lighting with 6000K or 100 FC average maintained. The results showed that focus lighting (higher brightness, cooler temperature) led to a higher percentage increase in oral reading fluency performance than normal (or control) lighting. The researchers indicated that further research on artificial light aspects and its effects on cognition, alertness, reading speed, and comprehension is needed.

The researchers in the aforesaid studies also concluded that there is indeed a significant relationship between light colour temperature and the level of comprehension and learning that an individual can exhibit (Lan, Hadji, Xia, & Lian, 2021; Barkmann, Wessolowski, & Markwort, 2012). Lan et. al (2021) have demonstrated that light illuminance and correlated colour temperature can influence occupants' mood and creativity. This research provides useful insights into the relationship between light and occupants' affective state, which is essential for tailoring the design of indoor lighting environments. It is important to consider the potential effects of different types of lighting, such as Variable Lighting (VL), on student performance and attitude when designing classroom environments. VL can have a positive effect on students' performance and attitude in the classroom according to Barkmann et al (2012). Data showed that students made fewer errors of omission and had faster reading speeds under VL, indicating that it can improve concentration and attention. There was no significant improvement in reading comprehension, but the students and teachers rated VL positively and found it useful during lessons. As such, designers can create an atmosphere that encourages occupants to work more effectively and efficiently through optimizing the lighting environment. Also, Variable Lighting (VL) and dynamic lighting maintain lighting that is most appropriate for the functions undertaken in an area, but the two systems mainly serve different needs, and therefore the implementation focuses on different aspects. VL offers modifications in the core parameters of lighting such as the colour or CCT, which can enhance the focus, reading performance and attention of students in accordance with Barkmann et al. (2012). In contrast, the change of dynamic lighting adjusts the level of parameters such as intensity and colour temperature in a cyclic order to conform to daylight changes or the need for certain activities. Whereas VL can be regarded as a type of dynamic lighting, the term dynamic should be understood from the perspective of efforts consistently made to alter the level of illumination in relation to a specific activity. As well, the viewpoint that distinct wavelengths are seen by the organism’s visual system is also incorrect since instead of individual wavelengths the organism’s visual system is responsive to wider areas of the visible spectrum. The eye sees only three ranges of colour through cone cells and rod cells such as blue or red and should not be looked for any and single wavelength which is important, especially when examining how various light conditions influence a human’s perception and cognitive through performance metrics.

4. The impact of light in the learning environment

Light has an immense impact on our bodies, so it makes sense to explore if changes in light intensity, illuminance, and temperature have any effect on human learning. The following section provides a detailed review of the literature concerning the impact of dynamic lighting systems on reading performance and investigates the connection between lighting and student reading performance.

Although there is a wide body of literature on correlated colour temperature (CCT), research concerning its application for students' reading speed and reading comprehension is relatively limited. The common definition of "light" is associated with a range of wavelengths by the ocular systems; light is thus distinguished from ultraviolet (UV) or infrared (IR) radiation, which is not perceived by the eye (Court, 2013). Visible light, then, defined by its physical properties, denotes the "visible portion of the electromagnetic radiation spectrum" occurring between the "ultraviolet and infrared portions, from 380 nm [to 780 nm]" (Pavan-Langsto, 2008: 298). Understanding the precise scientific parameters of light is imperative to efficacious interior design, especially in an educational context where cognitive function and mood regulation are crucial factors for individuals learning behaviour (Barkmann et al., 2012; Veitch &McColl, 2001)

4.2 Cognitive Implications of Lighting on Behaviourism

Students are required to perform several cognitive tasks in their educational institute throughout the day. It is important to develop educational settings to help the students in their performance of cognitive tasks, one of these aspects is to understand the impact of dynamic lighting on the execution of cognitive tasks among students.

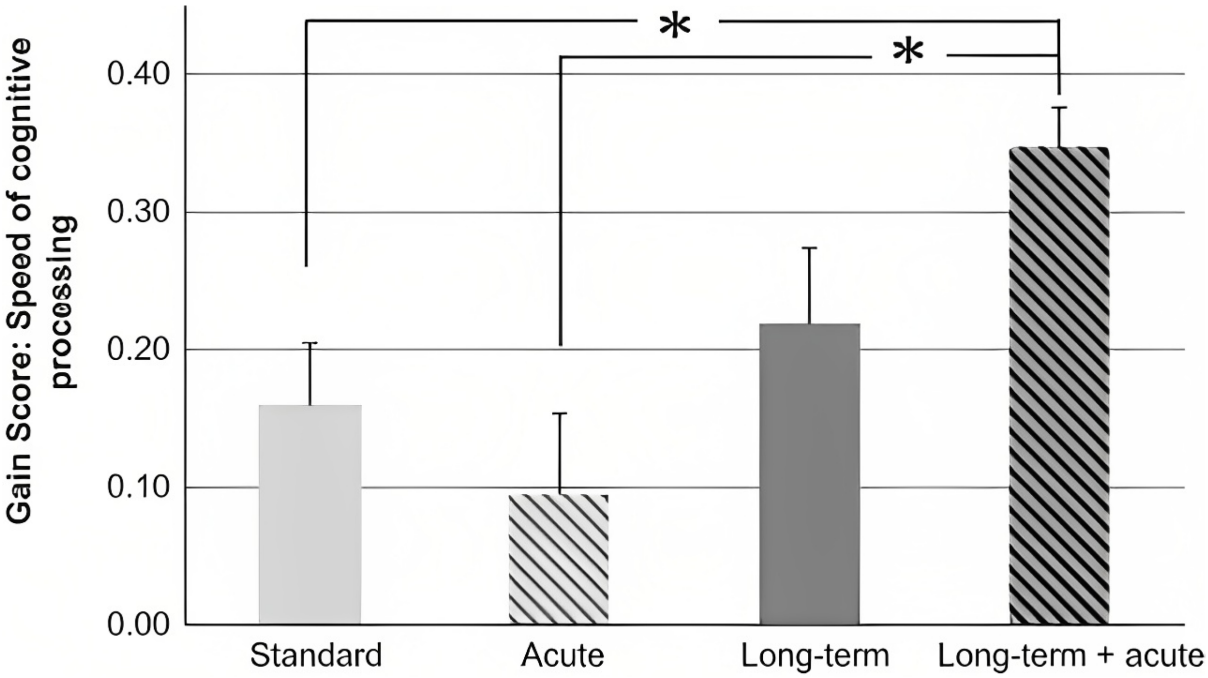

Figure 8 - Speed for Cognitive Processing Retrieved from (Keis et al., 2014)

The previous figure (figure 8) depicts the study of the cognitive processing speed in different situations of light exposure, and that acute lighting condition had the most notable enhancement, the graph shows that combination of the long term and acute conditions produced the most gain score surpassing both the long-term and acute condition independently. It is worth pointing out that the acute condition considered alone, displayed the least amount of improvement on cognitive processing, thereby indicating that alterations in lighting of such scale are less useful by themselves and need to be sustained over some period. The results suggest that the effective use of blue-enriched white lighting may boost the processing speed and concentration, provided that the enhancement is repeated often enough and used in conjunction with short-term changes. This finding highlights the need for further investigation about how both time exposure and type of lighting may contribute to optimal cognitive performance in the classrooms. The researchers sought to assess the speed of cognitive processing, which they attributed to the changes in the applied lighting conditions. The results revealed that the subjects exposed to the acute lighting condition demonstrated the most significant improvement in speed cognitive processing, The results also suggest that blue-enriched white lighting can have a positive effect on students' cognitive performance. It appears to improve their processing speed and concentration, though it does not seem to have any effect on their memory. The implications of this study suggest that introducing blue-enriched white lighting in classrooms could potentially improve the academic performance of students. Therefore, more research should be done to further explore the effects of different types of lighting on cognitive performance in students. (Keis et al., 2014).

Baron et al. (1992) conducted important research consisting of three studies that aimed to explore how lighting systems in indoor spaces impacted the performance of cognitive tasks. It also explored the impact of lighting on the interpersonal behaviours of people. This study focused on tasks that did not primarily require visual processing. This factor is important because, in the absence of such tasks, the impact of dynamic lighting on cognitive performance would be more evident.

The first study required that the participants rate a fictitious employee on several criteria for a job recommendation and overall competence when given a folder containing information about the employee’s negative and positive performance. They were asked to make their recommendations after studying the personnel file under different lighting conditions. They also had to match a set of given words to a topic. In the second study, the participants were exposed to either warm white light or cool white light and then provided scenarios where they had to resolve interpersonal relationships. The subjects were also asked to set goals for a clerical coding task for themselves. In the third study, subjects were divided into two groups. The first group received a small, unexpected gift while the second did not receive any gifts, In this situation, both groups were exposed to different lighting conditions. The study measured people’s tendency to engage in volunteer work and see which lighting condition impacted the decision more. The results of the studies revealed a general improvement in cognition and behaviour.

The results of the first study indicated that the subjects who were exposed to higher levels of illuminance gave lower performance appraisals to the fictitious employee in most categories as compared to those who were exposed to lower levels of illuminance. Additionally, the participants who were exposed to lower levels of illuminance included more words in broader word categories as compared to those who were exposed to higher levels of illuminance. In the second study, people who had been exposed to warm white light were found to be more open towards resolving their interpersonal conflicts by collaborating with others as opposed to the participants who were exposed to cool white light who were more likely to resolve their interpersonal conflicts through avoidance. There were also differences in self-goals set by participants for a clerical coding task. In the third study when the subjects were given a small, unexpected gift and exposed to warm white light, they were more likely than any other subjects to donate their time as unpaid volunteers. These three studies proved that light can be an important aspect of the environment that induces cognitive and behavioural changes in people when they are exposed to different conditions of light. Thus, environmental modifications especially change in illumination can impact their cognitive performance and their interpersonal interactions with others.

These results should be highly considered by educators who seek to improve students' academic performance as they spend most of their learning time indoors. If the lighting conditions are not optimal and implemented effectively in classrooms, their learning might be significantly affected. For example, their mood might be affected negatively, or they might feel sleepy due to the lighting conditions, which may end up decreasing their interest and concentration in the class. It is important to ensure that students do not face emotional or cognitive problems because of the poor lighting conditions. However, the ideal lighting conditions for a classroom remain a highly debated subject in scientific research.

4.3 Discourses on Colour and Academic Performance

Several studies, such as Shamsul et al. (2013), Gilavand (2016), Baafi (2020), and Casciani (2020), have acknowledged the importance of colour and quality of lighting to increase a student's academic performance, enhancing students' achievement, motivation, and boost concentration during learning in classrooms. Thus, researchers were interested in studying the ideal lighting conditions that could help reduce the visual impairment issues that arise from inadequate lighting in their learning spaces.

Cheatum and Hammond (2000) studied the visual problems of students in different schools. They pointed out that 20% of children enter schools with visual problems already impairing their ability to compete with their peers. These visual problems may include strabismus, lazy eye, training, eye tracking, focusing, etc which make their academic performance lower than their peers.

With such a significant number of students, the need for appropriate lighting can be considered extremely important because these students will continue to suffer if the appropriate lighting conditions are not implemented in schools.

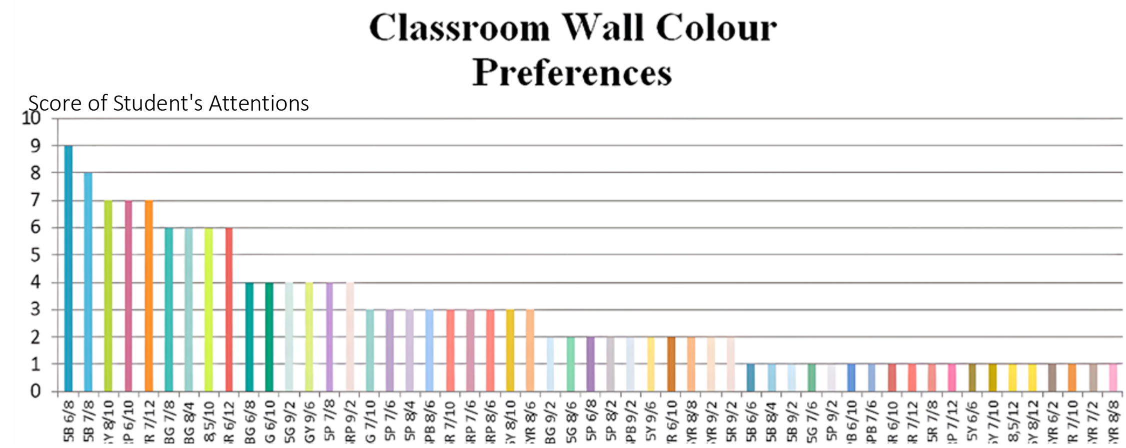

Figure 9 - Colour preference of students across different classrooms (Duyan & Ünver 2016)

Duyan and Ünver (2016) have demonstrated that the colour of classroom walls can influence the score of student's attentions. The results showed that cool colours such as purple, blue, and green had the highest attention scores, while red had the lowest. Furthermore, the private school students scored higher on every test in comparison to the state school students, suggesting that the student's environment can have a significant impact on their attentiveness. Therefore, it is important to consider the colour of classroom walls in order to optimize student performance and engagement.

The students who participated in the study aged between eight and nine years old. While the schools chosen were from different socio-economic backgrounds, the main aim of the research was to determine the implication of colours on school performance. In this regard, the focus was on the walls' colours, which form a significant part of the classroom ambience. The colours selected were among the common colours in classroom walls, they were selected using the Munsell Colour System. The researchers observed that students' level of attention depended on the varying wall colours. The results showed that the highest score was on the colour purple, which exhibited a result of 5P 7/8, while the lowest colour was red recording 5R 7/8. A curious contradiction can be observed between several studies on coloured preference and the ability to focus selective attention since students do not prefer the most optimal colours which are enhancing of attention such as purple (5P 7/8) and other colours like blue or green as exampled in the histogram. For example, whilst purple possessed the greatest level of focused attention by the subjects in the study of Duyan and Ünver, purple ranked third in terms of preference and red, the least popular in focused attention, still received a considerable preference. This discrepancy appears to be due to the difference between aesthetics and cognition since students would rather see red or other bright, familiar, attractive and rather visually suboptimal colours, which by definition, tend to be over-stimulating and distracting rather than enhancing focus. Thus, it can be recommended that classroom walls be painted with purple, blue and green in order to achieve maximum attention with bright purple colours and look for the latter for a secondary aim of aesthetics.

4.4 Relevant Deductions from Studies

The environment in which we learn can greatly influence our ability to focus, comprehend, and retain information. One important environmental factor is the colour temperature of the light in the learning space, which can affect the alertness, reading speed, and comprehension of students. Previous research has suggested that illumination can have a significant impact on learners' performance, but the results from research concerning the influence of colour temperature manipulation are mixed. The purpose of the current study is to examine the potential of manipulating the colour temperature of a learning environment to positively influence alertness, reading speed, and comprehension in students. The researcher in the present study supports this argument by exploring the results of previous studies, as well as discussing what implications these results may have for educators. In the following paragraphs, the researcher will first provide an overview of the existing literature on cognitive dynamics of lighting in learner and the learning process, then discuss the results of previous experiments, and finally, consider the implications of this research.

4.5 Cognitive Dynamics of Lighting in Learner and the Learning process

A study conducted by Winterbottom and Wilkins (2009) explored the impact of different features of lighting on the comfort level and cognitive performance of students in a classroom. The study aimed to explore which lighting conditions have negative effects on students. They indicated that different features of lighting in a classroom can be responsible for not only causing physical discomfort for the students but can also lead to impairments in their visual performance and degrade their cognitive abilities. The features that were expected to affect the students most significantly include unnoticeable 100 Hz flicker from fluorescent lighting and glare induced by daylight and fluorescent lighting, interactive whiteboards, and dry-erase whiteboard. This shows that in the classroom architecture and lighting should be designed in such a way that glare from natural and fluorescent lights is as limited as possible while also ensuring that dry-erase and interactive whiteboards are free of glare. The study was aimed at determining the magnitude and extent to which the lighting inefficiencies mentioned earlier exist in classrooms in the United Kingdom.

The results of the study showed abysmal lighting conditions in the majority of the classrooms because little attention is being paid to providing the students with satisfactory lighting conditions. The study revealed that the 100 Hz flicker was present from fluorescent lighting in an overwhelming majority of the surveyed classrooms. It was present in around 80 percent of the total classrooms that were included in the study. Other than that, the study also found that a large number of classrooms had installed fluorescent lighting that was highly inefficient and unnecessarily impairs the visual performance of the students while also being known to be a significant cause of headaches. The study also found out that some classes had a problem with lighting conditions where they had either excessive daylighting or excessive fluorescent lighting which ended up causing the classroom to be over-lit (Winterbottom & Wilkins, 2009, p. 9). This study shows that little attention is being paid to the lighting conditions in the classrooms and there is a dire need for schools to overhaul the lighting conditions in classrooms and make them more supportive of the student's learning. By improving these lighting conditions and ensuring that glare is minimized, students' visual problems can be minimized, and their learning performance will be enhanced.

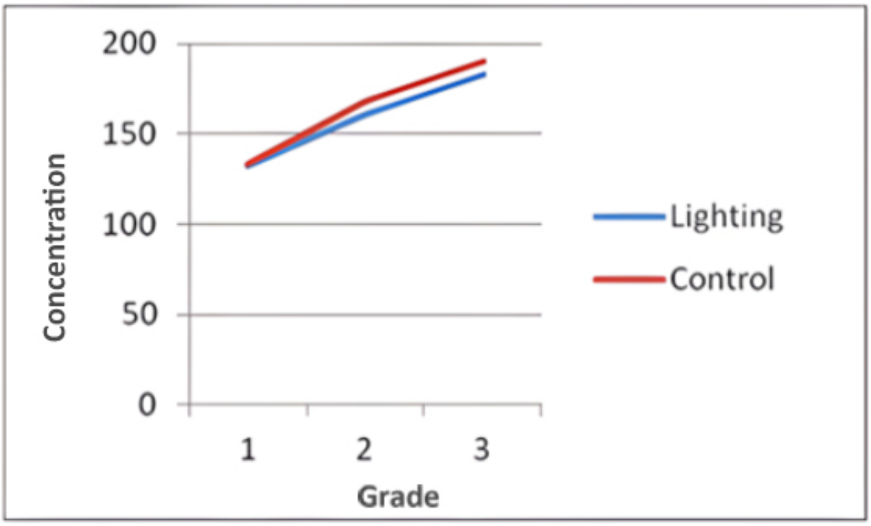

Figure 10 - Lighting and Concentration Results Retrieved from (Mott et al. 2012)

The chart illustrated above represents the results of a study focused on the effects of lighting on motivation and concentration among 84 third graders. The participants were exposed to either focus (6000K-100 Lux average maintained) or normal lighting. The researchers observed that there were no impacts of the lighting on both motivation and concentration. Nonetheless, the researchers further indicated that focus lighting conducted a higher percentage increase in oral reading fluency performance (36%) than control lighting (17%). This showed that colour temperature and illumination, can have a significant impact on student learning. These findings suggest that focus lighting can lead to higher reading fluency performance in third grade students. This indicates the need for further evaluation of the effects of illumination level and colour temperature variables on student learning outcomes. Careful consideration of lighting characteristics during the design and implementation of educational spaces is essential for optimizing the learning environment and promoting student success.

4.6 Implications of Lighting in Educational Settings

To explore which lighting conditions can be helpful, it is important to look for solutions that address the problem of lighting in schools. In 1976 Otto conducted a study that helped to present the benefits of lighting in classrooms to improve the behaviour of students with learning difficulties or those who are usually hyperactive. The study was conducted in four classrooms that did not have any windows. Otto (1976) examined first graders students in Sarasota, Florida. Further research has indicated that the colour of lighting can help individuals with dyslexia read by using coloured overlays or tinted lenses. According to Uccula et al. (2014), sensitivity to some light frequencies is often associated with visual stress, which can worsen reading impairment, while coloured overlays placed directly on the text alleviate symptoms. Lightstone et al. (1999) discovered that tinted lenses lessened visual discomfort and improved reading in children with reading disabilities, but the best effects are dependent on the positioning of the filter. Morrice et al. (2021) further explored the impact of various light sources and conditions on reading speeds, further confirming the possibility of customized lighting solutions to alleviate reading impairments. While evidence supports these methods, further rigorous studies are needed to confirm their efficacy and establish best practices.

In two classrooms, the researcher installed new full-spectrum fluorescent lighting while the other two rooms had the same standard fluorescent lighting commonly used for classrooms. Different cameras that had already been set up in the rooms prior to the experiment kept taking snapshots of these students to record how the difference in lighting impacted the students' behaviour. The results of the study showed that the students who were exposed to full-spectrum lit classrooms showed a significant improvement in their academic performance, and they showed higher levels of attention throughout the school day. On the other hand, the students who were placed in the other two rooms showed lower attention levels and thus, their performance was not as good as the experimental group. Based on these results, Otto (1976) concluded that behaviour and performance can be improved by improving the lighting conditions in the classroom.

Browning et al. (2014) discussed a range of biomorphic designs and stressed the importance of using architecture to ensure the achievement of the desired outcomes. In their biophilic design patterns, they explored the Dynamic and Diffused Light pattern of biomorphic designs. They believed that the productivity of students in a classroom will be improved when dynamic and diffused light is used in the design of the classrooms.

Another important study that should be mentioned here also studied the impact of colour and light on children's behaviours was conducted by Grangaard in 1995. The researcher studied the impact of colour and light on the behaviour of eleven 6 years elementary students. The study aimed to measure students' behaviours both off-task and on-task. They also measured the blood pressure changes of the students while they were in a classroom with white walls and cool white fluorescent lights and a classroom with light blue walls and Duro-test Vita-lice full spectrum lights. The researchers videotaped the students for 15 minutes every day. It was made sure that the videotapes were made at the same time every day for the sake of consistency in the results. The study revealed that students in the standard classroom engaged in a total of 390 off-task behaviours compared to 310 in the modified classroom, a 22% decrease. It was also found that the mean blood pressure levels of students in the modified classroom were 9% lower than in the standard classroom.
These findings show that educators and administrators in the school should recognize that "surroundings are never neutral" and that environmental changes in their classrooms must be implemented to provide the best possible environment that is conducive to students' learning and enhances their alertness.

4.7 Lighting and Design Elements

Tanner (2008) conducted a study that incorporated several school building design features that may be responsible for impacting the achievement of students. One of the most important factors that were revealed by the study was the lighting of the school building. Regression analyses revealed that Lighting was one of the factors that were shown to have a significant impact on the student's achievement in schools. The findings of the study were consistent with other studies that have delved into the impact of lighting in a classroom on student achievement. Browning et al. (2014) also reviewed several studies that emphasised the importance of lighting with various factors linked to achievement and performance. They discussed the importance of lighting with respect to the design of the building and how the presence of dynamic and natural light can be an important factor in improving the performance of the inhabitants of the buildings.

4.8 Daylight Lighting and Performance

It is important to review studies that examined and analysed the impact of daylight on the performance, mood, psychology, and overall well-being of humans in a particular building. Reviewing this literature is helpful in identifying the characteristics of desired indoor lighting that promotes benefits such as enhancing alertness and academic performance.

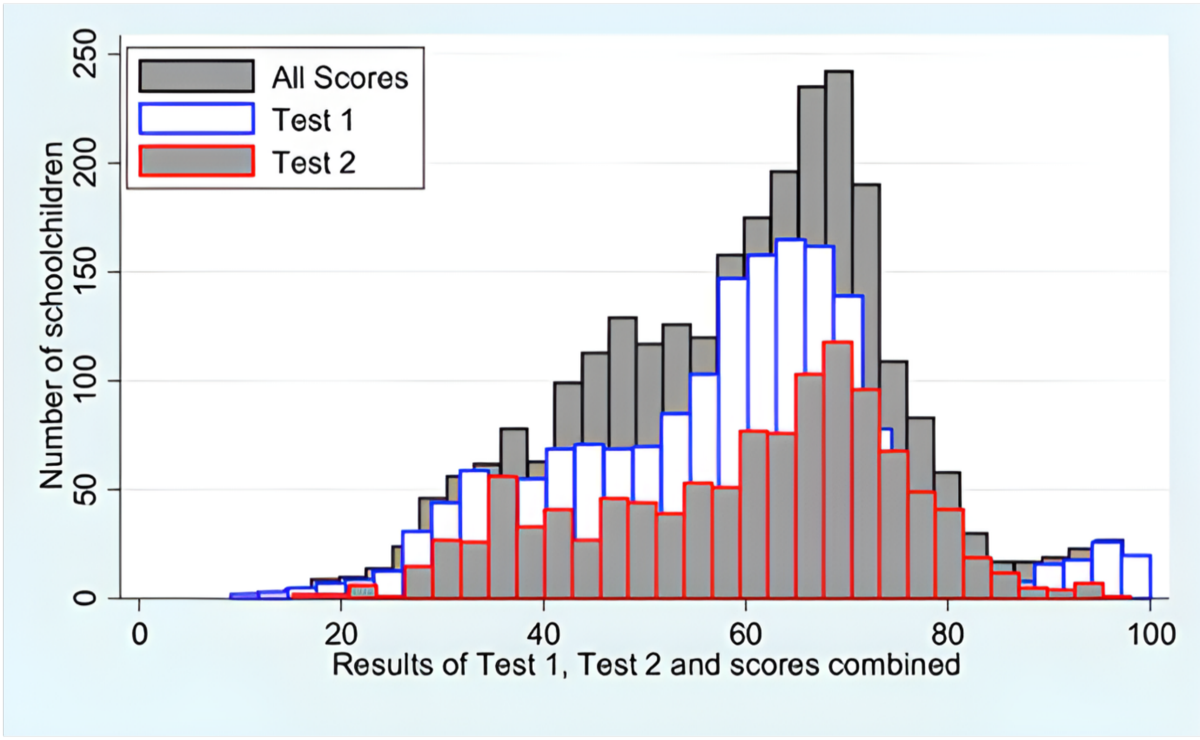

Figure 11 - Test results based on different times of the year retrieved from (Baloch et al, 2020)

Baloch et al (2020) conducted a study to assess the relationship between daylighting conditions in classrooms and mathematical and logical test scores. The sample consisted of 2670 elementary schoolchildren from 12 European countries. The results, as illustrated in figure 11, revealed that the average scores of the students across all the regions were higher during autumn and winter months and also that the school children performed best in October. Based on these outcomes, the researchers deduced that the aspect of lighting played a significant role in schoolchildren's performance. The increased test scores noticed in autumn and winter in the Baloch et al. (2020) study may be related to both environmental and biological reasons. The quality of natural light is, at this time of year, more diffuse and cooler in CCT; this is beneficial, for example, for enhancing alertness and cognitive performance as if it were daylight. In addition, fewer hours of daylight may help students' daily rhythms to be more in sync with class hours and hence help students to be more alert when attending classes. However, one can argue that the increased number of hours of daylight in spring and summer would hamper sleep patterns which could be detrimental to performance. The specific seasonal effects bringing increased structure and less external stimuli in autumn and winter are also valid and might strengthen with regard to academic performance.

Similarly, Heschong et al. (1999) conducted a study to identify the benefits of daylight for students in an academic setting. The sample consisted of students from second to fifth grade. A total of 2000 classrooms were included in the study, all of which were in three districts. The researchers conditioned the daylight settings for all of the 2000 classrooms. Daylight conditions were rated for each classroom on a scale of 0 to 5 where 0 signified no daylight and 5 signified excellent daylight conditions with other options in between.

The results of the step-wise regression analysis indicated that daylight was a significant factor in improving the performance of the students in both mathematics and reading. Furthermore, students in the classrooms with the highest Window Code, i.e. classes with better windows, showed a significant improvement in their academic performance as compared to their colleagues in classrooms where windows had major obstructions towards daylight or were small.

This result guides the designers of these classrooms to ensure that the artificial lighting should stimulate the daylight as much as possible because of the positive impacts of the daylight on students.

4.9 Implications of Changes in Dynamic Lighting

Sleegers et al. (2012) conducted three experiments to investigate the effect of dynamic lighting conditions in classrooms on students' achievement. The first two experiments, both quasi-experimental field studies, were conducted on sample sizes of 89 and 37 students respectively. The third experiment was a randomized laboratory experiment on a sample size of 55. The researchers used the d2-test to measure students' concentration, which assesses speed and accuracy.

Results from the first two experiments showed a significant potential for the lighting system to affect students' concentration. However, the third experiment found no statistically significant impact of the lighting system on the concentration of the students. While both the experimental and control groups showed improved performance, the experimental group exhibited significantly greater improvement.

The difference in findings between the first two experiments and the third could be explained by the different settings of the experiments.
The researchers identified three variables of lighting conditions that may have a significant effect on the learning environment in an indoor setting namely illumination, and colour temperature. The variations in these variables can potentially have an impact on school and work performance, concentration, motivation, focus, mood, and sleeping patterns (Mott et al., 2012).

Mott and colleagues conducted their study to explore the impact of lighting conditions on students' learning by experimenting on 84 third-grade students. The students were exposed to either normal lighting or focus lighting where a 6000K-100fc average was maintained to increase focus

The most prominent difference lay in the oral reading fluency performance test of the students. Focus lighting resulted in a significant improvement in the oral reading fluency performance of the students with an increase of 36%. However, participants in the control lighting conditions showed only a 16% increase in the oral reading fluency performance test. However, there was no significant effect of lighting in increasing either concentration or motivation among the students.

4.10 Implications of Lighting Dynamics on Physiological and Emotional States

Research has shown that the physiological and emotional states of students can be impacted positively or negatively with the help of different colours. A study conducted by Al-Ayash et al. (2015) explored the impact of six colours (pale yellow, pale blue, pale red, vivid yellow, vivid blue, and vivid red) on the learning performance, heart rate, and emotions of the students.

The results of the study confirmed that different colours had a different impact on the subjects. Although the pale colours made the subjects feel calmer and more relaxed, the participants scored considerably higher in their reading scores when they were exposed to vivid colours. Yellow and red conditions were more likely to increase the heart rate, while blue colour helped the participants feel calmer and more relaxed than any other colour. These results revealed that reading can be improved with the use of vivid colours in the environment. In addition, it showed that it is possible to manipulate physiological functions in the human body such as heart rate and invoke feelings of calmness and relaxation using different colours (AL-Ayash et al., 2015).

Numerous studies have shown the positive implications of lighting on the brain and bodily function. Farghly et al. (2020), Zhang et al. (2021), Vitalevna et al. (2020), de Vries et al. (2018), and Cajochen et al. (2019) have noted that lighting impacts respiration rates, blood pressure, biorhythms, alertness, and wakefulness. In addition, lighting has been found to facilitate the secretion of hormones such as cortisol and melatonin, as well as regulate mood and cognitive functions (Department of Veterans Affairs Medical Centre, 2016). Galetzka et al. (2012) also demonstrated that certain variations in lighting can lead to cooperative learning in pedagogically optimal environments. Lastly, Winterbottom and Wilkins (2009) found that specific variations in lighting can influence cognition and visual apprehension, which are important for reading speed and comprehension.

As for reading speed and comprehension specifically, Barkmann et al. (2012) conducted a study, which revealed a significant correlation between lighting conditions and reading rate/accuracy.

Despite clear evidence that different kinds of lighting input result in remarkably varied psycho-physiological outputs, “to date, there have been few empirical studies of the effects of special lighting techniques on school-based academic performance or the well-being of students” (Barkmann et al., 2012: 621). In other words, despite the evidence that lighting conditions can affect pupils’ achievement and behaviour, empirical evidence from research conducted in the educational field is still very limited.

Thus, the current study suggests that a controlled artificial lighting system could be implemented in classrooms to create a pedagogically optimal learning environment that is conducive to boosting reading speed and comprehension. Two key factors will be considered in this lighting system: colour temperature, measured in kelvin (K), and illuminance, measured in lux.

Previous research found that, in respect of literacy and numeracy in primary school students, brighter lighting (500 lux) yielded improved results when compared with standard lighting (300 lux). Rautkyla et al. (2010) has shown that the correlated colour temperature (CCT) of white light, as well as the timing of the light exposure, have a significant influence on student alertness in lecture environments. In autumn, students exposed to a 17,000 K light source were found to maintain higher levels of alertness than those exposed to a 4,000 K light. In spring, however, no correlation between the CCT of light and alertness was detected. It is suggested that the more intense exposure to outdoor daylight during spring lectures caused the students to remain more alert. Furthermore, the study found that eating promoted the post-lunch dip in alertness, even in the presence of cool white light. This should be further investigated to better understand the link between eating and alertness. The results of this study provide valuable information that can be used to improve student alertness and productivity in lecture settings. The same study also held that variations in colour temperature (between 4000 K and 17000 K) led to a wide variety of positive outcomes in students, including increased attendance, alertness, and overall achievement.

Hence, "dynamic lighting" (namely, "lighting that enables diverse lighting settings, in precise combinations of illuminance and CCT") appears to be a vital factor in the improvement and growth of academic performance (Barkmann et al., 2012; Majoros, 2001). The inquiry of Barkmann confirmed that adjustable lighting is a feasible technology for enhancing the learning environment in school classrooms. The results demonstrate that variable lighting (VL) can augment students' performance by augmenting their focus and reading speed, even if the effects on reading comprehension were not statistically noteworthy. Additionally, the students and teachers rated VL positively and found it advantageous during classes. Therefore, VL has the potential to benefit both the academic performance and the wellbeing of schoolchildren. These findings have meaningful implications for the design of classrooms in schools and imply that further investigation is needed to explore the potential of VL to upgrade learning results.

4.11 Overall Deductions from Literature

Research has connected dynamic lighting with positive effects and behavioural outcomes, reading speed, and reduced instances of student aggression (Berman et al., 2011). They indicated that dynamic lighting systems yield positive results in terms of students' performance, attainment, concentration, cognition, well-being, mood, and behaviour - though, it should be noted that some research opposes the claimed benefits of dynamic lighting (Iszo, 2001). On the other hand, the majority of research endorsed the idea that colour temperature is a significant determining factor in learning outcomes. These Studies' main objective was to assess the influence of CCT on overall learning ability. Thus, more research is needed to explore this relationship with specific academic competencies such as reading comprehension and reading speed. Shen and colleagues (2017) have also identified mental alertness as being a factor of interest in academic performance. Dynamic lighting patterns were found to produce the greatest results, with students reporting better sleep quality and, indeed, self-perception (Kuller and Wetterberg, 1993).

A review conducted by Hansen et al. (2017) explored the strategies used to assess the impact of dynamic lighting in learning environments. It was found that a combination of methods is essential for determining the effects of dynamic lighting, such as academic performance, behaviour, and mood. Therefore, dynamic lighting should be addressed through a design-driven innovation approach that incorporates multiple methods.

To sum up, the current study aims to illustrate the importance of providing optimal lighting systems which can be a possible contribution to future research that might guide the design of educational spaces. Also, the researcher will assess the potential effect of using different lighting temperatures to create improvement in educational performance, with the hope that sustained improvements lead, over time, to greater educational achievement.

5. Aim and Objectives

The experiments in the current study are designed to achieve the following aims and purposes.

5.1 Aim

The aim of the current research study is to identify the effect of colour temperature on reading and how different levels of colour temperature may impact students' educational performance, and to subsequently derive recommendations for how the lighting in a learning environment can be optimised.

5.2 Objectives

a. To provide a detailed and comparative investigation into five different levels of colour temperature, measured at 2,500K, 3,000K, 4000K, 5,000K, and 6,500K, and to compare the impacts of these settings to normal office lighting.

b. To assess how the characteristics of these types of lighting may influence students' performance concerning educational performance, as characterised by:

- Level of alertness at the time of study
- Reading speed levels at the time of study
- Levels of comprehension at the time of study

The following chapter explains the methodology that will be followed and how the objectives and aims of this study will be achieved.

V. Theoretical Framework

VI. Methodology

The primary objective of this project is to investigate the effects of varying colour temperatures on students 'alertness, reading speed, and comprehension within an imitating and real educational context. Hence the research question is as follows:

Does colour temperature affect students' alertness reading speed and comprehension?

While a randomized controlled trial is often considered the gold standard for research, it might not be the most feasible option for the current study. A quasi-experimental approach can be a strong justification in a laboratory setting for the following reasons:
1. A lab setting allows to create more controlled lighting scenarios that students might encounter in classrooms or libraries.
2. It helps to manipulate the lighting conditions within the lab, allowing to test a wider range of CCTs and measure their impact on student performance.
The subsections that follow describe how the study was carried out, beginning with a description of the experiment settings, followed by a description of the participants, a description of the measures, and an analysis of the results.

1. Experiments

This study comprised two laboratory experiments that were conducted to explore the impact of different lighting conditions on the reading speed and comprehension of the students, and their level of alertness. In both experiments, the participants were given different light conditions and they were scored on two scales to ascertain the impact of those lighting conditions on their reading abilities and alertness. The two tests that were employed in both experiments were Reading (speed and comprehension) tests (Appendix 10), and The Karolinska Sleepiness Scale (KSS) (Appendix 6). The two experiments were similar in many aspects but with one major difference. In the first experiment, the lighting conditions varied only by the CCT. In the second experiment, the lighting conditions varied by both CCT and brightness levels. The rationale behind conducting these experiments separately was to ascertain the impact of lighting temperature when brightness is constant as opposed to impact of different lighting temperatures when brightness levels are variant. This would allow presenting a clear validation of the impact of colour temperature on the reading ability of the students.

2. Participants

For both laboratory studies, participants were recruited using convenience sampling, with information about the study published at Leeds University, where the research was conducted. Before the students were accepted to participate in this study, they were screened to see if they were fit for participation - especially, since they did not have any health conditions that could skew the results. They answered questions (Appendix 3) to ensure that they did not have prior health conditions such as epilepsy, no eyesight impairments, or learning difficulties such as dyslexia. This process of carrying out a health screening assessment is to ensure the validity of the results and, further, to ensure that participant subjects are not placed in uncomfortable or dangerous situations. All testing took place outside of class hours. This screening was carried out for the participants of both experiments.

Six undergraduate and graduate students were chosen for the first experiment, with the only variation in the lighting circumstances was the CCT. For the second experiment, a sample size of 30 undergraduate students was chosen using the aforementioned criteria, with the lighting conditions varied in terms of CCT and brightness levels.

3. Ethical Considerations

The Faculty of Arts, Humanities, and Cultures Research Ethics Committee at the University of Leeds examined all experiments before they began to verify that no subjects were endangered and that all ethical considerations had been taken into account. (Appendices 1 and 2). Informed consent for the study for both experiments was obtained via a link to an online sign-up sheet which was sent to all participants prior to each study commencement (Appendices 4 and 5). The participants were initially informed that the experiments were intended to examine the accuracy of reading-based assessments. After finishing their participation, the selected sample was provided with a comprehensive summary of the study, and they were given the opportunity to keep in touch with the researcher conducting the study and receive updates about the findings.

4. Setting and Lights

The first two experiments were conducted at a psychophysical laboratory at the University of Leeds, allowing for more accurate lighting control, which is crucial for conducting an exploratory study of this nature. This allowed for eliminating the effect of potential confounding variables when examining the results of tests. Participants sat at individual workstations, each with a lamp and a set of printed reading materials on plain A4 white paper, and the lab only allowed one participant to participate at a time. LED lights were used in both trials, allowing for accurate computerised calibration to the temperatures listed below.:

- 6,500K (Daylight)
- 5,000K (Natural White)
- 4,000K (Cool White)
- 3,000K (Warm White)
- 2,500K (Soft White)

As mentioned earlier, the first experiment solely assessed variations in CCT, whereas the subsequent experiment examined differences in both CCT and brightness. The CCTs for the second experiment were the same as the first experiment i.e., 6500K, 5000K, 4000K, 3000K, and 2500K. The second experiment examined the influence of three different brightness settings – 275Lux, 475 Lux, and 613 Lux - in addition to temperature conditions. The lighting was deliberately positioned above the participants. Hence in the second experiment, there are three brightness levels: 275, 475, and 675 lux. Under each brightness level, there are five color temperatures: 6500K (Daylight), 5000K (Natural White), 4000K (Cool White), 3000K (Warm White), and 2500K (Soft White). Furthermore, each day, one brightness level was tested along with all five colour temperatures: 6500K, 5000K, 4000K, 3000K, and 2500K.

This means that the study involved testing 15 different lighting combinations over three days. Each day, one of the three brightness levels (275 lux, 475 lux, or 675 lux) was paired with all five colour temperatures. This allowed the researcher to investigate the effects of both brightness and colour temperature on student performance and alertness.

LED lights were chosen for their energy-saving potential and cheap cost (Hawes et al., 2011), both of which are key considerations that must be taken into account in the design of educational establishments. To imitate most lighting setup in these structures, the lighting was placed overhead in the lab. (Federal Highway Administration, 2017).

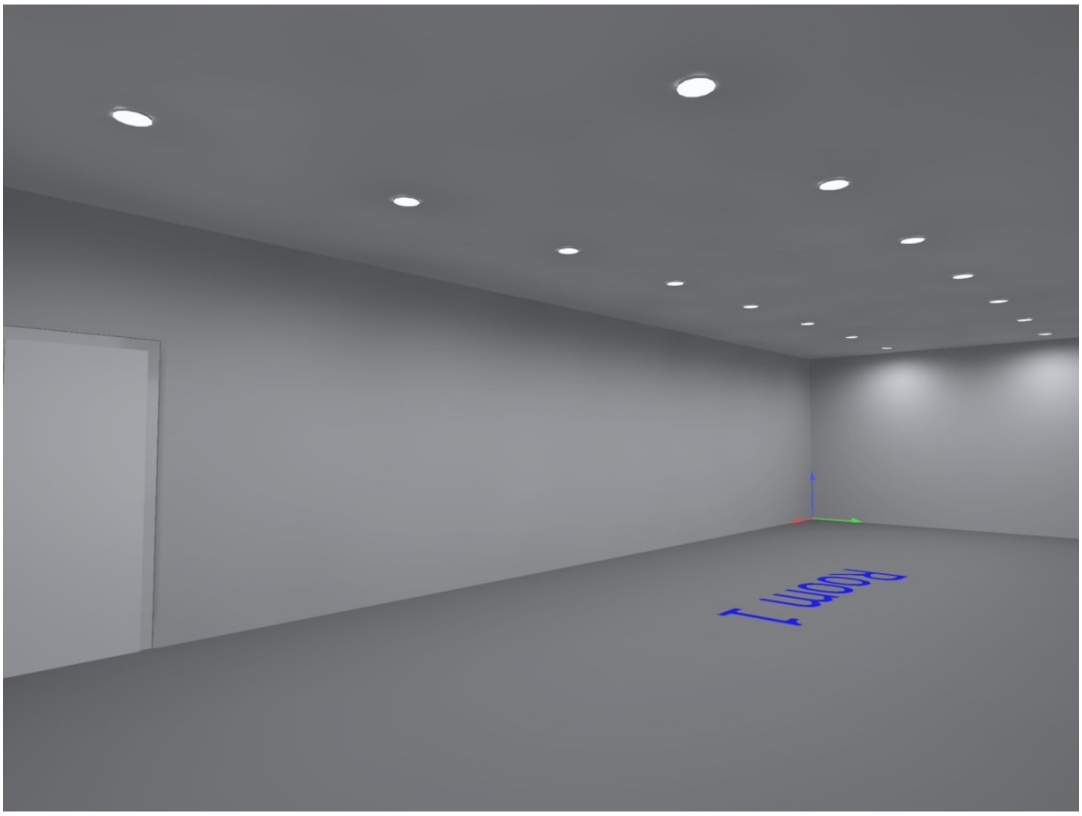

Figure12 - A simulation of the psychophysical laboratory at the University of Leeds with regular office lighting

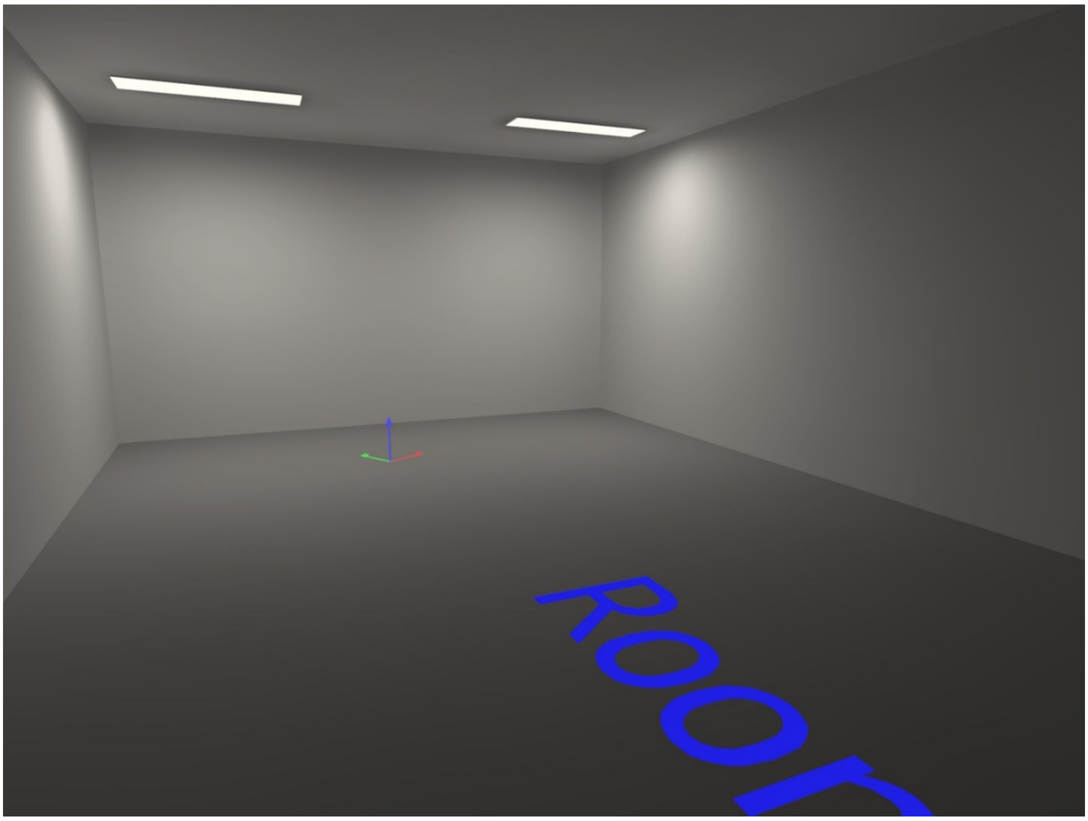

Figure 13 - A simulation of the psychophysical laboratory at the University of Leeds after applying 3000K 475 Lux lighting

5. Measures

For the laboratory experiments, the following tests were administrated to determine the effect of the lights.

a) Reading (speed and comprehension) tests

Reading speed and comprehension was measured using texts from an online website: http://www.freereadingtest.com/. This website was selected because it provides a wide range of texts, differing levels of difficulty, and different story adaptations. These texts were used to guarantee that participants were not bored while reading and that any recall effect was eliminated. When the reader is ready to begin reading, they should select a topic, level, and story number, then press the "begin" button. When they finished reading, they pressed the 'done reading' button and were asked to complete a comprehension test based on the text they had just read. All participants were obligated to read the same topic and story and were tested at the same level.

b) Karolinska Sleepiness Scale

The Karolinska Sleepiness Scale (KSS) examines a person's sleepiness/alertness. It determines the subjectively rated level of sleepiness during a specific moment in the day. The participants indicate which score best reflects the physical and psychological state they have experienced in the preceding 10 minutes. The Karolinska Sleepiness Scale (KSS) is a measure of situational somnolence; it is vulnerable to variations, in a nine-point rating system (1 = highly alert, 3 = alert, 5 = neither alert nor tired, 7 = tired but not having any difficulty staying awake, 9 = extremely tired and fighting sleep). The Karolinska Sleepiness Scale (KSS) is a well-suited tool for measuring subjective alertness in your study investigating the effect of CCT on student performance in a laboratory setting. Strengths of the KSS for the current research:

1.Simplicity and Ease of Use: The KSS is a self-administered, 9-point scale with clear descriptors ranging from "extremely sleepy - fighting sleep" to "wide awake - full of alertness." This makes it easy for participants to understand and report their current level of alertness.
2. Validity and Reliability: The KSS is a well-validated and reliable measure of subjective sleepiness. Numerous studies have established its effectiveness in assessing alertness in various research contexts.
3. Sensitivity to Changes in Alertness: The KSS is sensitive enough to detect changes in alertness levels that might occur due to exposure to different CCT conditions in your lab setting.
4. Non-Intrusiveness: The KSS is a quick and non-invasive measure, minimizing disruption to the study protocol and participant experience in the lab environment (Federal Highway Administration, 2017; Smolders, 2012).

6. Procedure

In both experiments, the first task consisted of getting a base reading for the sample using regular office lighting levels. Following that, participants completed a reading test and the KSS questionnaire. The experiment began after baseline measures were taken. Experiment 1 consisted of reading of a general topic at Level 7 and had the participants read story number 1 for the reading test. Experiment 2 had a reading test that comprised of Topic- General, Level- 8, and Story number- 1.

Each trial lasted one hour, and participants spent equal amounts of time at each lighting level. Each CCT test required the participant to complete a reading test as well as the KSS questionnaire. Each CCT test was separated by a 10-minute pause. Because experiment 1 only had one level of brightness, it was performed in a single day. While experiment 2 lasted three days, each day was dedicated to reading at different brightness levels. On the first day, the reading for the lowest brightness level, 275, was taken. The subjects were tested at a brightness level of 475 on the second day, and 613 on the third day. Each test conducted at different CCTs required the participant to complete a reading exam as well as the KSS questionnaire. Each test conducted at different CCTs was separated by a 10-minute pause. Below is an image of one of the volunteers under 275 LUX brightness and 3000K colour temperature.

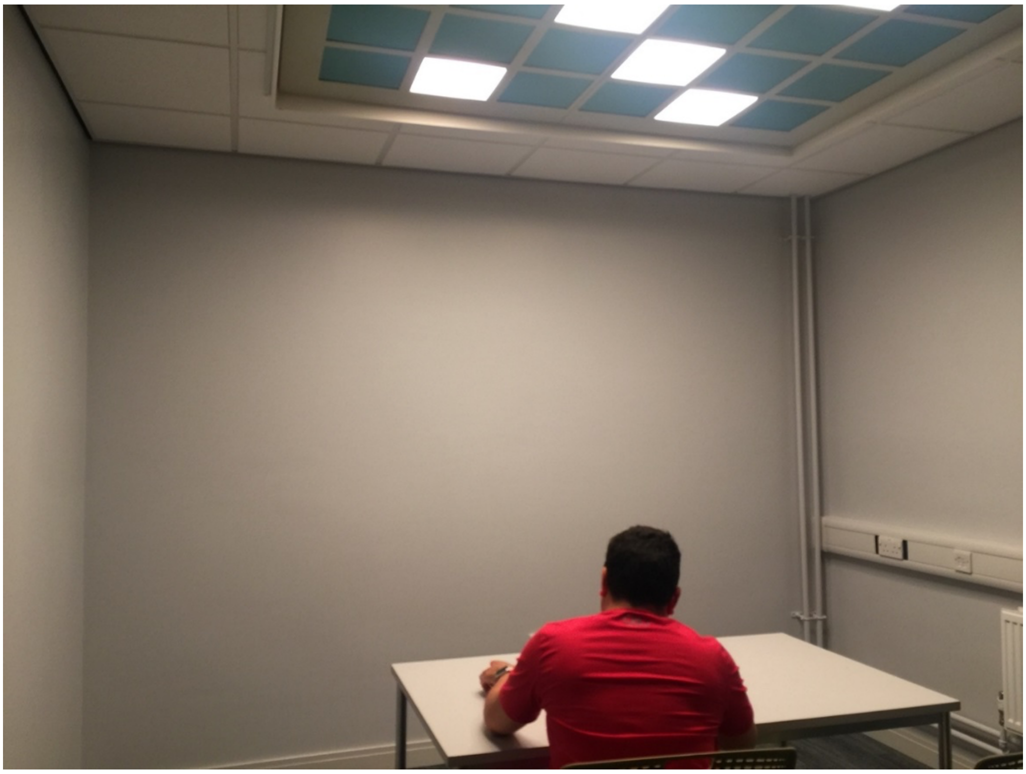

Figure 14 - A participant during reading test under a 275 LUX brightness and 3000K color temperature.

To assess reading under the various conditions, the following conditions were employed:

a) First experiment

Baseline: Topic: General, Level: 7 Story: 1;

6500K: Topic: General, Level: 5 Story: 2;

5000K: Topic: General, Level: 5 Story: 3;

4000K: Topic: Fun Facts, Level: 5, Story: 1;

3000K: Topic: Fun Facts, Level: 5 Story: 2;

2500K: Topic: Fun Facts, Level: 5 Story: 3.

b) Second experiment

Baseline: Topic: General, Level: 8 Story: 1;

6500K 275 Lux: Topic: General, Level: 7 Story: 1;

5000K 275 Lux: Topic: General, Level: 7 Story: 2;

4000K 275 Lux: Topic: General, Level: 7, Story: 3;

3000K 275 Lux: Topic: Fun Facts, Level: 7 Story: 1;

2500K 275 Lux: Topic: Fun Facts, Level: 7 Story: 2.

6500K 475 Lux: Topic: Fun Facts, Level: 7 Story: 3;

5000K 475 Lux: Topic: American History, Level: 7 Story: 1;

4000K 475 Lux: Topic: American History, Level: 7, Story: 2;

3000K 475 Lux: Topic: Earth & Space Science, Level: 7 Story: 1;

2500K 475 Lux: Topic: Earth & Space Science, Level: 7 Story: 2.

6500K 613 Lux: Topic: Earth & Space Science, Level: 7 Story: 3;

5000K 613 Lux: Topic: American History, Level: 7 Story: 3;

4000K 613 Lux: Topic: Fun Facts, Level: 8, Story: 1;

3000K 613 Lux: Topic: Fun Facts, Level: 8 Story: 2;

2500K 613 Lux: Topic: Fun Facts, Level: 8 Story: 3.

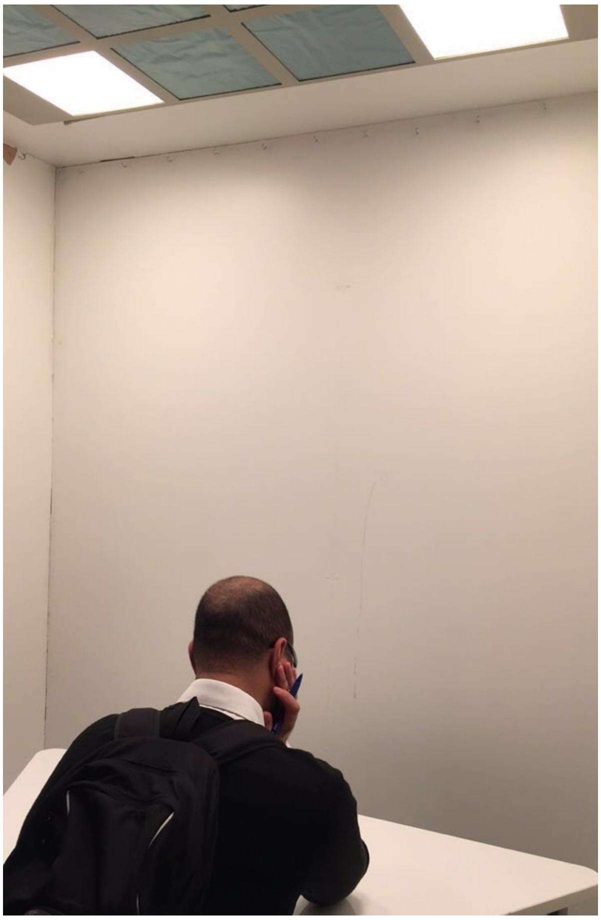

Figure 15 - A participant during reading test under a 2500K light source

Before the participants arrived, all equipment were properly set up, such as laptops, lights/lamps, and blinds, to guarantee that no other light source compromised the experiment. Brightness and colour temperature was controlled using two devices:
Sekonic C-7000 Spectrometer: This device is used to measure colour temperature. It can accurately measure the spectral distribution of light, which allows for precise determination of the colour temperature in Kelvin (K).
Lux meter: This device is used to measure the illuminance or brightness of light. It measures the luminous flux per unit of area, typically in lux (lx).

Figure 16 Sekonic C-7000 Spectrometer device

Figure 17 Lux meter device

7. Data Analysis

For the first experiment, the sample size was small. The small sample size meant that only descriptive statistics could be used. These statistics were calculated using the Microsoft Excel program.

For the second experiment, the data for each of the 30 participants were recorded for all three variables of interest: sleepiness level, speed and comprehension at each temperature, and brightness level, following the example in table 3 below.

Participant 1																Name-Date
Normal	6500			5000			4000			3000			2500			Kelvin
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX
																1 Karolinska Sleepiness Scale
																2
		*												*		3
												*				4
	*			*		*		*			*				*	5
*			*		*		*		*	*			*			6
																7
																8
																9
107	119	163	80	175	143	110	96	100	115	126	123	127	155	161	94	speed
25	100	50	50	100	75	100	75	75	100	100	75	75	100	100	75	comprehension

Table 3 - Values for the three variables recorded for subject number 1

The data was organised and processed in the Microsoft Excel program. Both descriptive statistics and inferential statistics were calculated using SPSS program to analyse the results of the second experiment.

The data generated from the above-mentioned experimental approach and data analytic strategy will be presented in the following chapter. Data for all three variables of interest were collected for each of the 50 participants: sleepiness level, speed and comprehension at each temperature, and brightness level. Microsoft Excel was used to organise and sort the data. To analyse the outcomes of the field study, descriptive and inferential statistics were calculated using the SPSS programme.

VII. Results

This chapter will examine the data gathered from the first and the second experiment and the statistical analysis of these results.

1. First experiment Results

As noted earlier in the Methodology chapter, the sample in this study comprised 6 participants, consequently, only descriptive analysis was used to determine:

a. Mean scores and measures of spread (using the range) across all CCTs.

b. A comparison between individual performance scores in different CCTs to baseline measurements.

c. Mean scores and measures of spread (utilising the range) of differences between baseline scores and experimental temperature scores.

This analysis will be detailed for each of the three dependent variables namely, KSS scores, reading speed scores, and comprehension scores.

1.1 The impact of CCT on KSS performance

This section will present the KSS scores of the sample used in this experiment and clarify how these scores varied with the manipulation of CCT. Figure 18 illustrates the mean scores of the KSS test at baseline (*M*=3.5, range 1-5), and across the range of CCTs utilised in the study. A lower score on the KSS test indicates a higher level of alertness (refer to Appendix 6 for further detail). Scores for the KSS at a CCT of 2,500K indicate a decrease in alertness (*M* = 4.5, range 2-6).

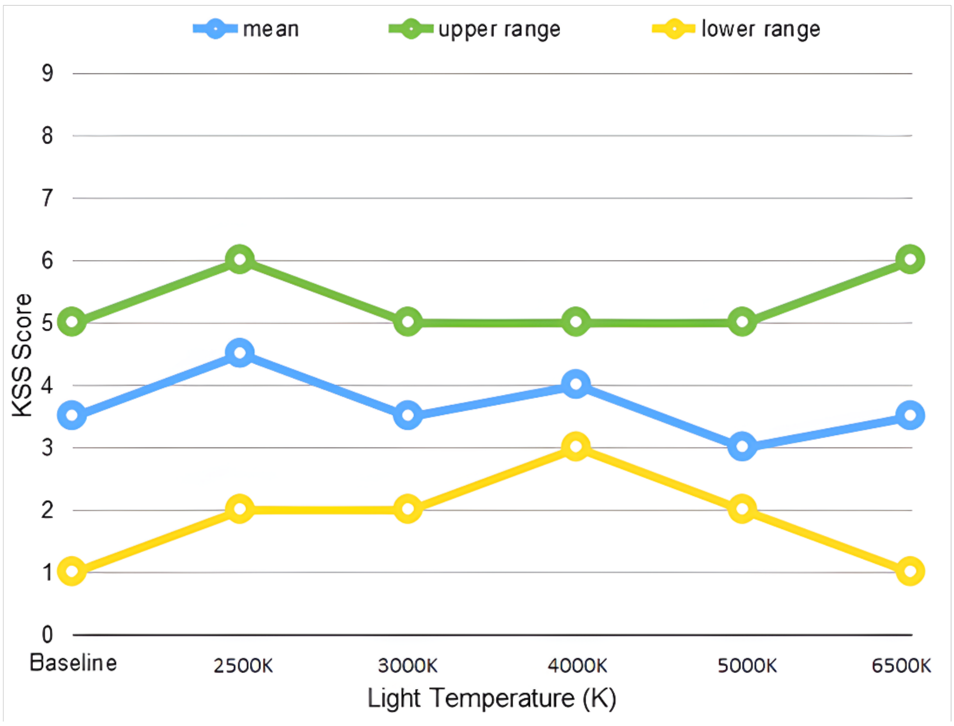

Figure 18 - CCT and Mean KSS Scores

As Figure 18 shows, at a CCT of 5,000K, participants demonstrated the lowest collective scores (*M* = 3, range 2-5) and the highest collective levels of alertness. It is noteworthy that the level of spread of scores was most centered around 4,000K of

CCT (*M* = 4, range 3-5), and the highest variability of scores was observed at 6,500K (*M* = 3.5, range 1-6). A detailed explanation of these results, as well as all subsequent results, will be discussed in the following chapter.

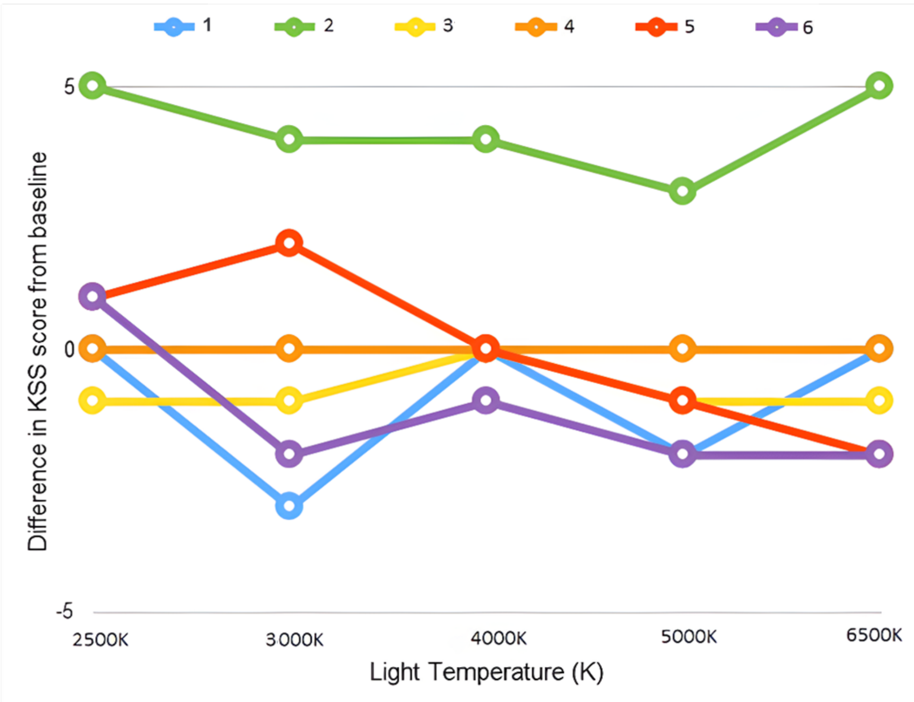

Figure 19 - Changes from Baseline - KSS Scores and CCT

Another aspect to be considered is the differences in individual participants' scores across the varying levels of CCT (2,500K - 6,000K). Figure 19 above, provides a depiction of scores for all of the experiments' participants, in comparison to their baseline KSS scores measured at the start of the experiment. It demonstrates that one participant in the experiment ('participant 2') scored higher on the KSS across all CCTs, compared to baseline scores. The scores of the other participants, however, do not replicate the performance of this outlier score.

The scores on the KSS once the CCT is manipulated tend to be stable or lower compared to baseline KSS scores for these five participants. With CCTs of both 5,000K and 6,000K all five participants scored lower or the same as at baseline on the KSS and all demonstrated similar or increased levels of alertness compared to baseline. The figure also illustrates the individual changes from baseline KSS scores over the varied CCT for different subjects where each line corresponds to a subject. It is relevant to say that disrespecting all the light's temperature, second subject scored highest in KSS, which means she has reported more tiredness and less alertness when compared with the rest. This outcome can be attributed to a number of factors. One of such reasons could be that it is the expectations that participant number 2 may have contributed to the high scores. Since KSS observer 2 had fixed lighting conditions in his mind, she must have affected the alertness and mood to a great extent. Or it could be due to other extraneous variables, for example participant 2's baseline sleep quality, their rhythm, individual's sensitivity to lighting is only some of the variables that determine how an individual reacts to light exposure. In addition, as you mention in p. 31, morning and evening may also determine what effect this correlated colour temperature has. For example, it may be that CCTs around 5000K or 6000K may produce some effects in subject depending on the time of day of the lights that are closest to natural daylight.

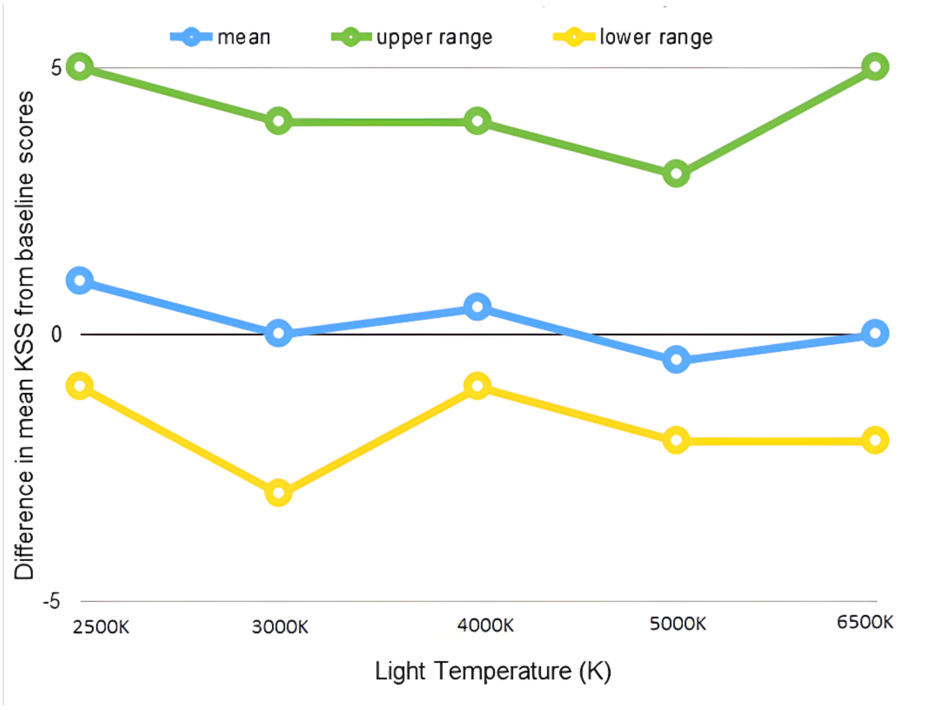

Figure 20 - Mean differences in KSS Scores Compared to Baseline

The mean differences in these scores were examined to determine the collective impact of changes to KSS scores from baseline across experimental CCTs. Figure 20 shows the mean differences in KSS scores compared to baseline scores, including the upper and lower range of mean differences. The scores of participants 2 (discussed above) are seen to be driving the upper ranges across the various CCTs. The mean changes to KSS scores compared to baseline are slight due to the small sample size and the outlier score. The results reveals that there is no change in mean scores of the KSS test at 6,500K, despite the upper range reaching its highest point.

We can infer from this that the scores for the other participants would be lower on average, as supported by the individual scores outlined in Figure 21.

Increasing the number of participants would not have an effect on the magnitude of deviation that the mean of changes to KSS scores would exhibit. Instead, having more participants would enable the negative effect of outliers like participant 2 to be minimised since a broader and more representative sample would be more obtainable. Presently though the small sample size narrows the extreme values, which in turn changes the mean and increases the variability in the findings. With the introduction of more participants, a situation whereby individual scores are considerably less than the average of the group is likely to be recorded. The mean in this regard would be more stable and in line with the expected trend. Thus, while the deviation may remain present, it would most probably seem less marked in relation to the general dataset. Furthermore, findings could be more robust and generalizable since the sample size gives better statistical power to effectively test important features.

1.2 The Impact of CCT on Reading Speed

In this section, we will examine the reading speed scores of all six participants in this experiment. First, their average scores at baseline and across the various experimental CCT settings will be assessed, and then examine the individual performances compared to baseline, and collective differences compared to baseline performance.

Figure 22 reveals that at baseline, the mean reading speed score was 86.5 words (range 63-114). These average reading speeds remain relatively stable across CCT settings, except for the 4,000K CCT setting (M = 95.3, range 63 - 148). This is however the CCT with the greatest measure of spread. It is worth noting that the two CCTs with the closest level of variability are 3,000K (showed a decreased mean reading speed of 78.8 words), and 5,000K which was roughly similar speed to baseline (M = 85.5, range 58-103).

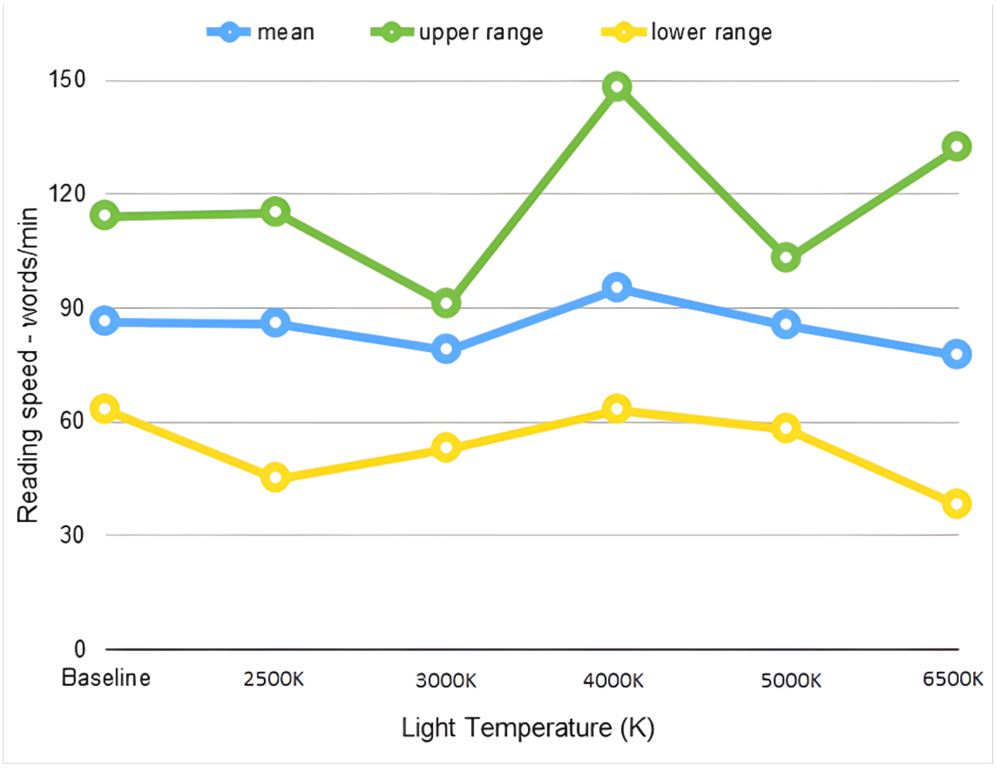

Figure 21 - CCT and Mean Reading Speed

When examining differences from baseline performance, we shall first examine the individual performances of all six participants. Figure 22 below shows these individual changes to reading scores across all levels of the CCT when compared to baseline performance. The results illustrated in Figure 20 support the previous assertion that the temperature setting which showed the most promising results was 4,000K - in which there was an individual who performed noticeably better (participant 6) at this level. However, this is also the only CCT setting in which most participants performed better compared to baseline (4 out of the 6 participants improved their reading speed, albeit modestly in the case of 3 of them).

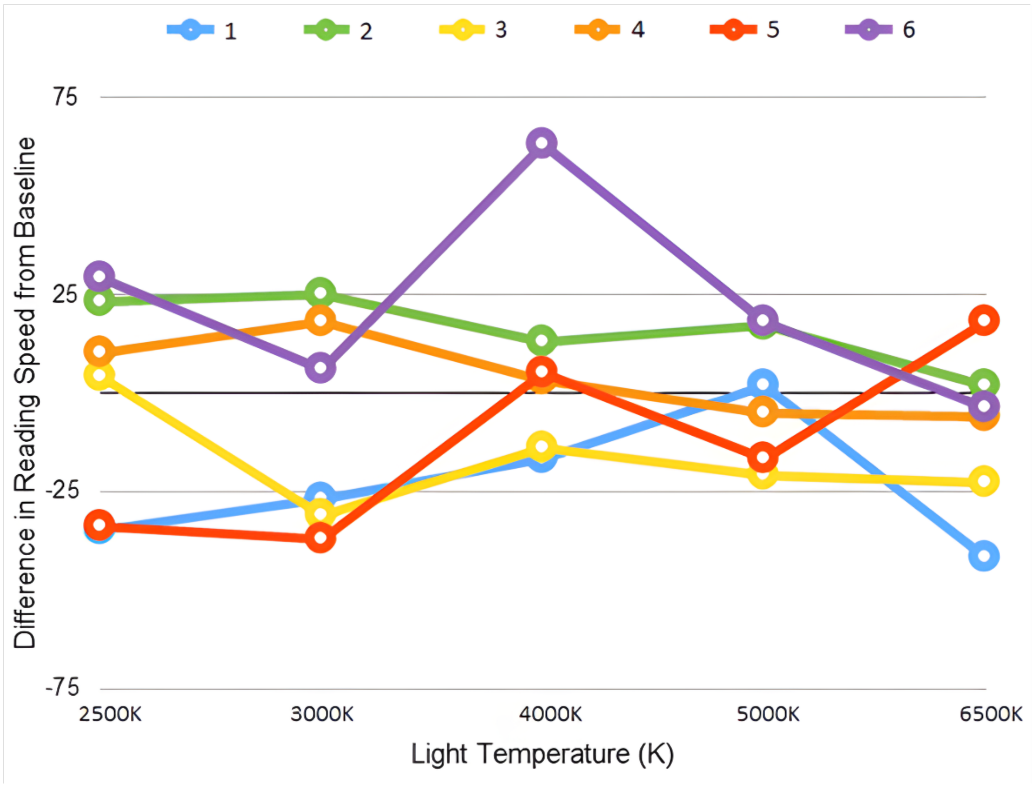

Figure 22 - Individual Changes from Baseline of Reading Speed Across CCTs

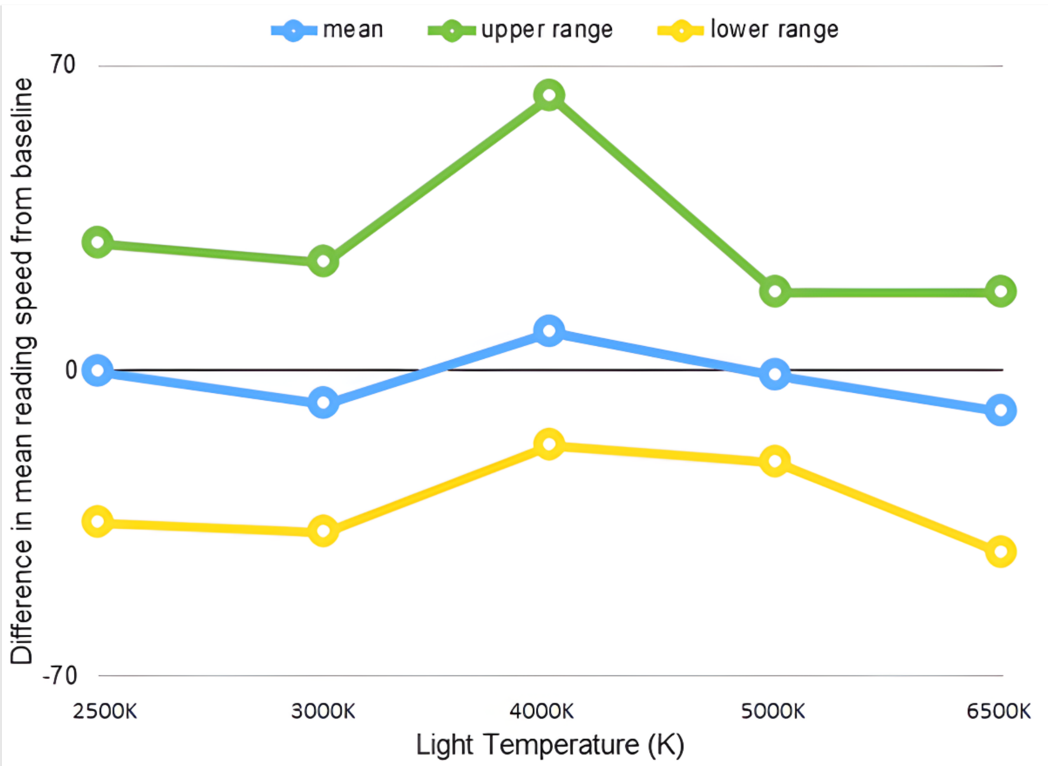

Figure 23 - Mean Differences in Reading Speed Compared to Baseline Performance

Figure 23, also highlights that the temperature of 4,000K of being of most interest in the improvement of reading speed (mean improvement of 8.8 words, range -17 to 63).

1.3 The Impact of CCT on Comprehension

This section will present the results of the reading comprehension scores, as observed at baseline and across the various experimental CCT settings. Figure 24 illustrates the collective mean and range of scores at baseline (M= 66.6, range 50-100) and across the experimental temperature settings. It indicates that as CCT increases from baseline, comprehension scores increase as well, peaking at the 5,000K setting (M= 91.2, range 75-100), which also indicates the smallest variability in scores out of all the temperature settings used in the Experiment.

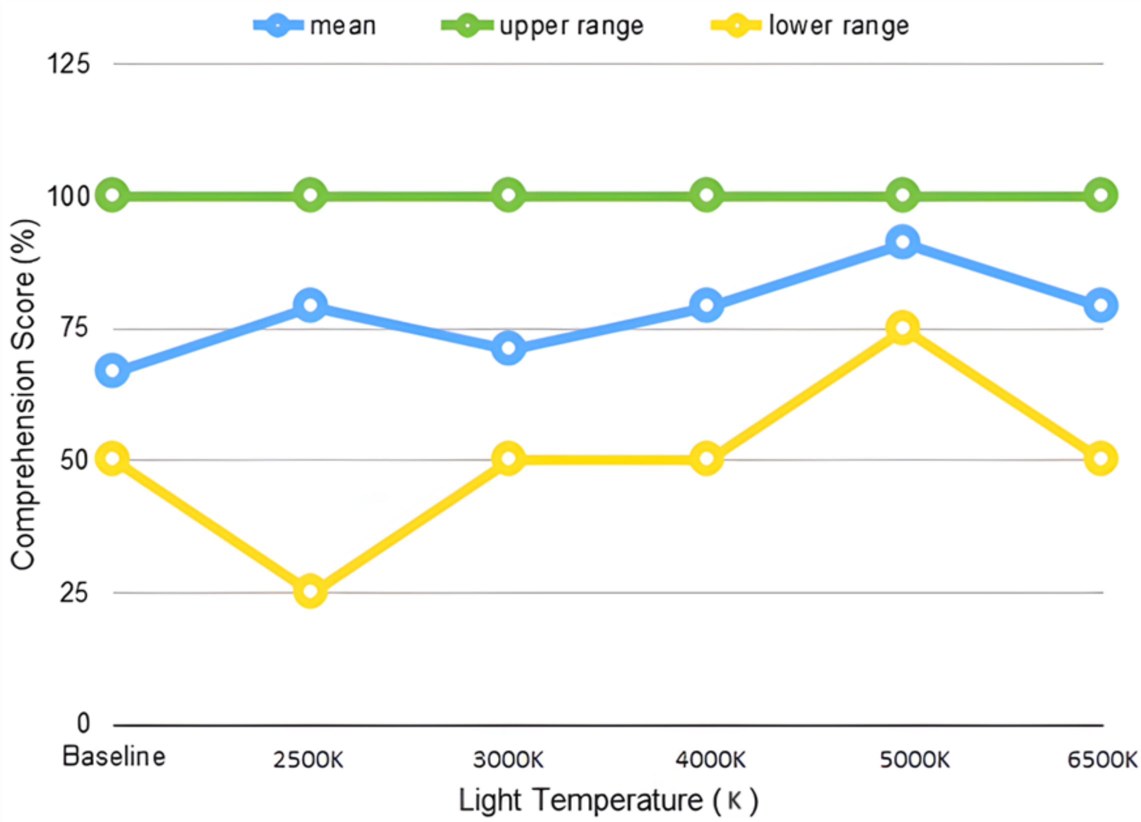

Figure 24 - CCT and Comprehension

Figure 25 details individual improvements or reductions in comprehension scores for each of the participants in this study, when compared to their performance at baseline. The current results support the previous finding that 5,000K appears to be the best CCT to improve students' comprehension performance. 5 out of the 6 participants improved their scores while the remaining participant maintained his score close to the baseline. Unlike the findings relating to KSS scoring and reading speed improvement, no outlier score was detected.

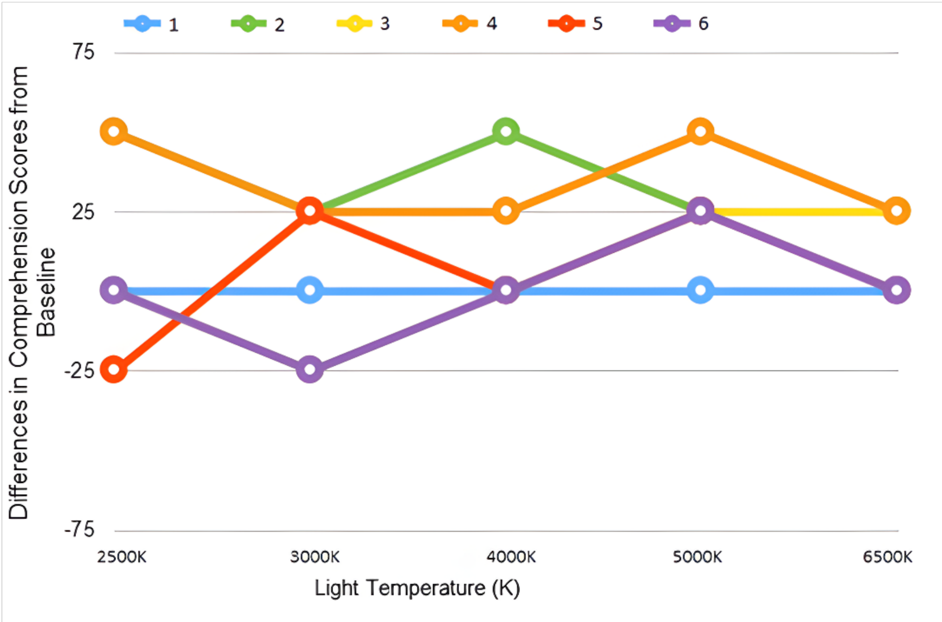

Figure 25 - Individual Changes from Baseline in Comprehension Scores

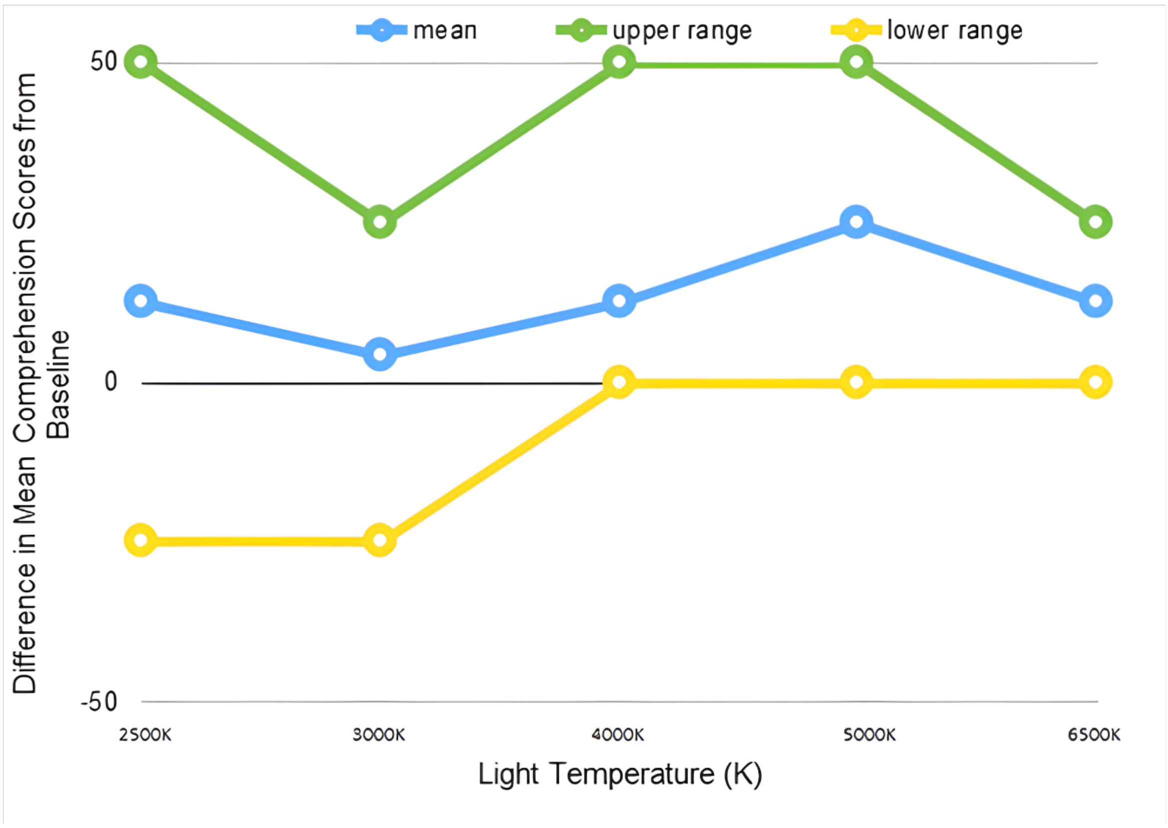

Figure 26 - Collective Differences in Comprehension Compared to Baseline

The results presented in figure 26 also support the main finding that 5,000K was related to the best change in reading comprehension scores, but also indicate that a lighting temperature of 6,500K may be of further interest to study. Although the average improvement in comprehension scores was lower at 6,500 (*M* = +12.5) compared to at 5,000K (*M* = +25), the variability of scores at 6,500 was much more closely grouped (0-25) compared to at 5,000 (0-50).

The result that 5000 K is connected with the highest level of reading comprehension improvement is consistent with earlier investigations like in Winterbottom and Wilkins (2009) and Freund et al. 2014 which emphasize the advantages of using colour temperatures varying between 5000K and 6500K for cognitive tasks as they are close to the natural daylight. The lower degree of variability of scores at 6500K implies that such a lighting condition tends to bring about uniform results over different people, which is also important in educational contexts in order to attain uniform results. The results also show that the mean improvement at the 6500K average is lower than that of the 5000K which indicates that 6500K may present a stable condition but 5000 K may be better in achieving performance peaks. This interplay between efficacy and consistency suggests that 6500K would still be interesting for further studies emphasizing tasks that require prolonged attention as well as for different target populations to clarify the unique advantages of this condition.

2. Second Experiment Results

2.1 Karolinska Sleepiness Scale Averages (KSSA)

After the data was properly organised mean scores were calculated for all three variables of interest as recorded for every lighting condition used in the experiment. The results are reported below (Table 3).

Karolinska Sleepiness Scale Averages (KSSA)	
2500K 275 Lux	6.1 KSS
2500K 475 Lux	5.03 KSS
2500K 613 Lux	4.63 KSS

3000K 275 Lux	5.16 KSS
3000K 475 Lux	4.93 KSS
3000K 613 Lux	5.06 KSS
4000K 275 Lux	5.43 KSS
4000K 475 Lux	4.96 KSS
4000K 613 Lux	4.73 KSS
5000K 275 Lux	5.6 KSS
5000K 475 Lux	4.66 KSS
5000K 613 Lux	4.16 KSS
6500K 275 Lux	5.66 KSS
6500K 475 Lux	4.03 KSS
6500K 613 Lux	3.73 KSS
NOL* 460 Lux	4.73 KSS

Table 3 – Mean values recorded for sleepiness level

** Normal Office Light (NOL)*

A higher value recorded on the Karolinska Sleepiness Scale (KSS) corresponds to a higher level of sleepiness (1= 'extremely alert', 9= 'very sleepy, great effort to keep awake, fighting sleep') (Akerstedt et al., 2014). As observable in table 4 above, the Mean score values recorded for this variable ranged from 3.73 to 6.1. Both these values represent the extremes of the range with the lowest value (KSSA=3.73) being recorded for 6500K, 613 Lux and the highest (KSSA=6.1) for 2500K and 275 Lux.

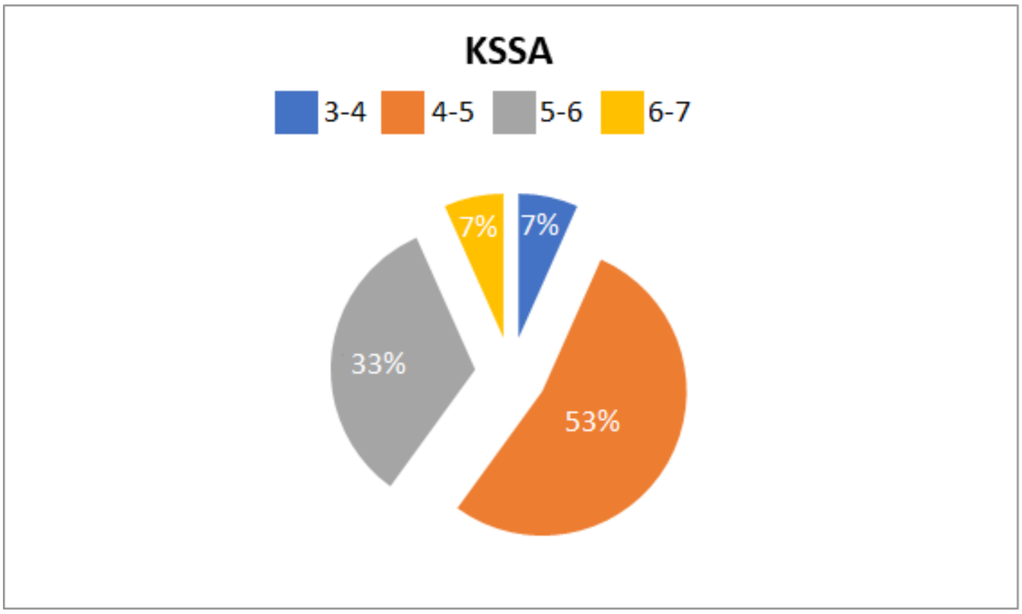

Figure 27 - KSSA frequency

According to figure 27, 53% of the values were between 4 and 5, with the remaining 33% falling between 5 and 6. For Normal Office Light (NOL460K) the KSSA average was 4.73 therefore within the highest frequency range obtained.

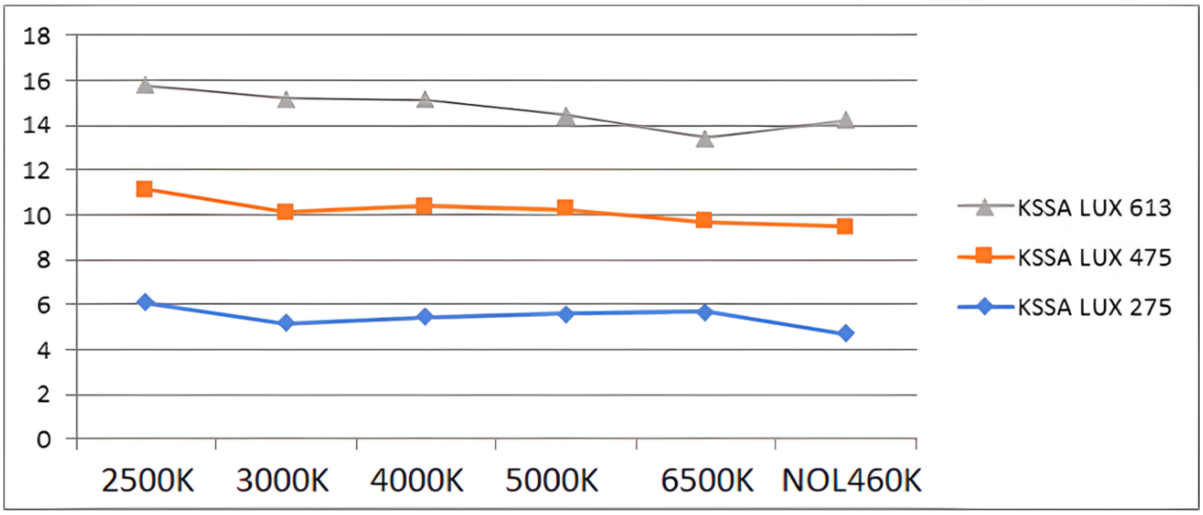

Figure 28 - KSSA 275 Lux, 475 Lux and 613 Lux comparative values

For 275 Lux the greatest difference was noted between the value recorded at 2500K and 3000K (Figure 28). The sleepiness value recorded for 'Normal office light' was lower than the lowest value recorded at 275 Lux (Figure 28). A lower variance of values was recorded for KSSA at 475 Lux. In this case, the lowest value was recorded at 6500K (Figure 28). Compared to the previous Lux levels the values recorded for 613 Lux yielded the highest variance. The highest value was recorded for 3000K and the lowest for 6500K (Figure 28).

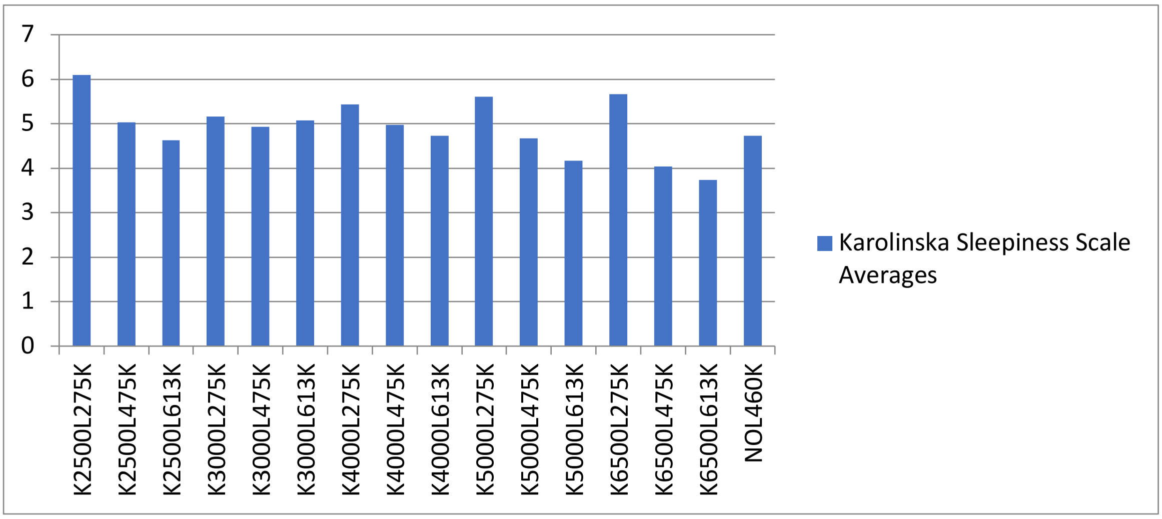

Figure 29 - Overall KSSA comparative values

The lowest KSSA value overall was recorded for 6500K at 613 Lux. The following closest values were for 6500K 475 Lux and 5000K 613Lux. The KSSA for 'normal office light' ranged higher than any of these (Figure 29).

2.2 Speed averages (SA)

Speed Averages (SA)	Reading speed
2500K 275Lux Speed	105.5667
2500K 475Lux Speed	110.2
2500K 613 Lux Speed	147.9
3000K 275 Lux Speed	155.63
3000K 475 Lux Speed	128.33
3000K 613 Lux Speed	110.86
4000K 275 Lux Speed	283.5
4000K 475 Lux Speed	92.83
4000K 613 Lux Speed	139.96
5000K 275 Lux Speed	135.96
5000K 475 Lux Speed	111.03
5000K 613 Lux Speed	99.76
6500K 275 Lux Speed	126.8
6500K 475 Lux Speed	252.86
6500K 613 Lux Speed	131.73
NOL 460 Speed *	134.43

Table 4 – Mean scores values recorded for speed level

** Normal Office Light (NOL)*

Mean scores values were estimated for reading speed level for which the general values recorded ranged from a minimum of 48 (subject no. 6 at 2500K 613 Lux Speed) to a maximum of 660 (subject no. 18 at 4000K 275 Lux Speed). The mean scores ranged from 92.83 to 283.5. The highest mean value was recorded at 4000K 275 Lux while the lowest value was recorded at 4000K 475 Lux (Table 4).

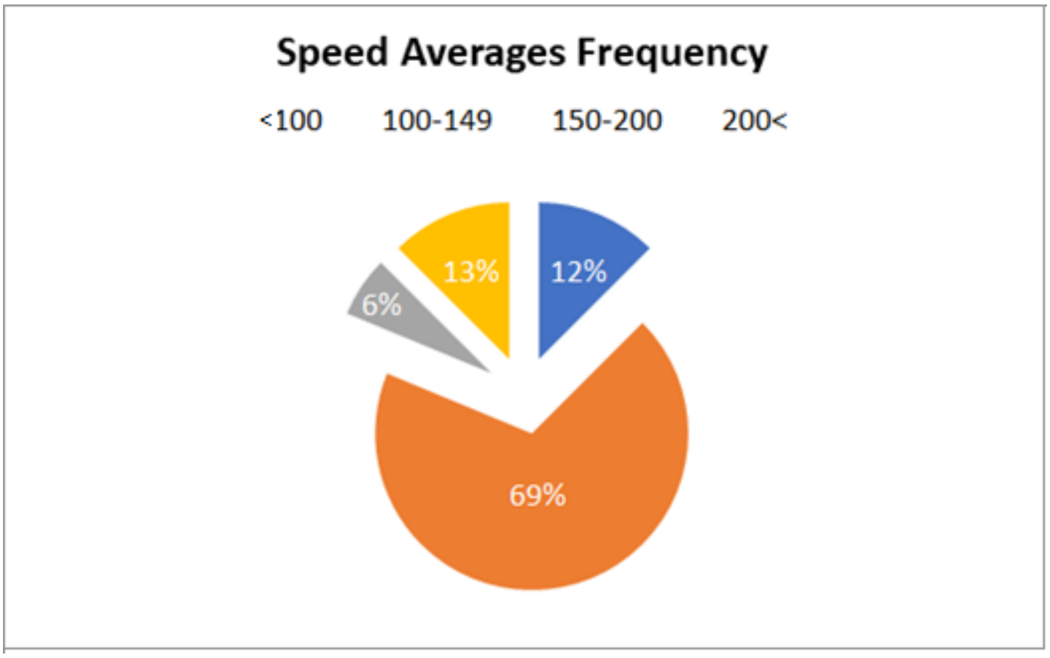

Figure 30 – Speed Averages (SA) Frequency

The highest average reading speed (69%) was within the interval of 100-149, whereas the lowest average speed (6%) was within the interval of 150-200. Notably, the extreme values (SA=92.83 and SA=283.5) were both in similar frequency intervals (12% and 13% respectively) (Figure 30).

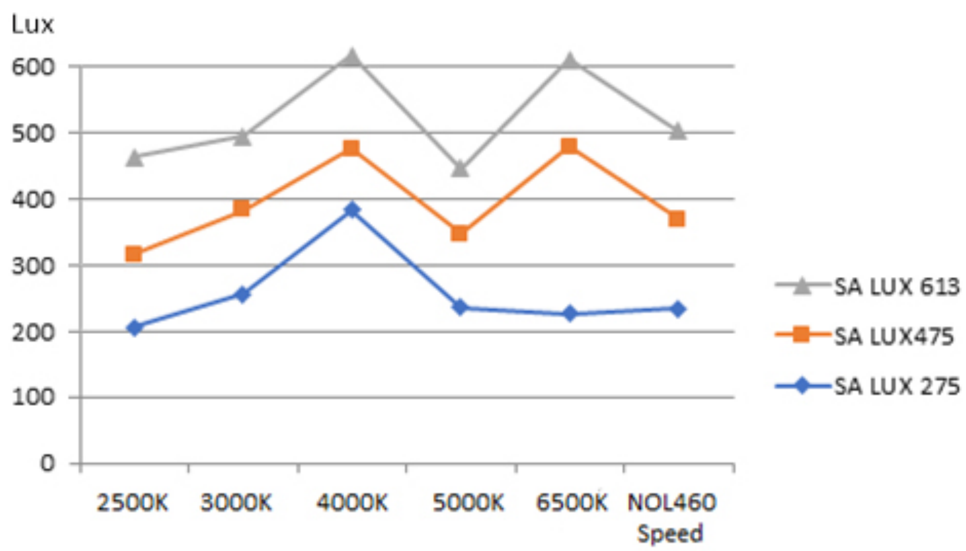

Figure 31 - SA 275 Lux, 475 Lux and 613 Lux comparative values

When observing the mean scores for reading speed for 275 Lux it was noted that the highest was recorded for 4000K, whereas the lowest was recorded for 2500K. The mean value recorded for normal office light was most similar to the one recorded for

5000K at 275 Lux (Figure 31). For 475 Lux the highest SA was recorded at 6500K. Similar to the condition of 275 Lux, for 475 Lux the highest SA was significantly different than the SA values obtained for the other Kelvin conditions (Figure 31). Analysis of Figure 31 reveals that SA values were most homogenous at 613 Lux. The highest value was obtained for 2500K, but this did not differ significantly from the subsequent highest values (4000K and 6500K). Additionally, the SA value recorded for 'normal office light' was closer to the highest SA value obtained at 613 Lux than to the lowest (Figure 31).

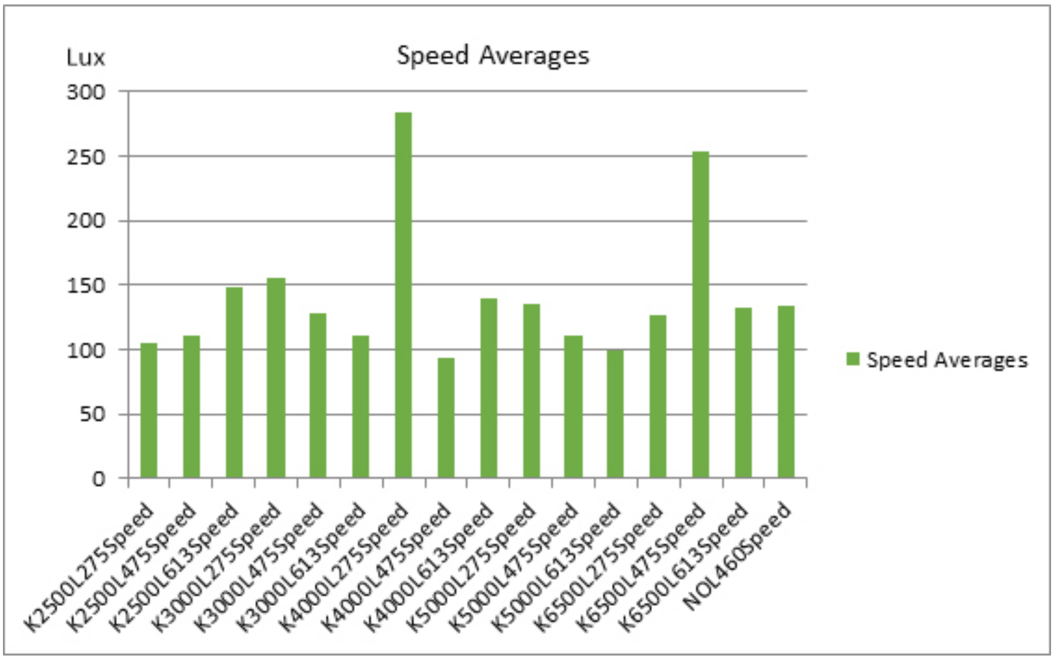

Figure 32 - Overall SA comparative values

The highest SA values overall were recorded for 4000K 275 Lux and 6500K 475 Lux (Figure 32).

2.3 Comprehension averages (CA)

Comprehension Averages	
2500K 275 Lux Comprehension	35
2500K 475 Lux Comprehension	50
2500K 613 Lux Comprehension	46.66
3000K 275 Lux Comprehension	45
3000K 475 Lux Comprehension	50
3000K 613 Lux Comprehension	51.66
4000K 275 Lux Comprehension	45
4000K 475 Lux Comprehension	64.16
4000K 613 Lux Comprehension	38.33
5000K 275 Lux Comprehension	50
5000K 475 Lux Comprehension	51.66
5000K 613 Lux Comprehension	62.5
6500K 275 Lux Comprehension	45
6500K 475 Lux Comprehension	50.83
6500K 613 Lux Comprehension	58.33
NOL* 460 Lux Comprehension	36.66

Table 5 - Average values recorded for comprehension level

** Normal Office Light (NOL)*

Table 5 reports the mean values calculated for comprehension level for each of the lighting conditions considered. The lowest mean value is 35 (recorded for 2500K 275 Lux Comprehension) and the highest is 64.16 (recorded for 4000K 475 Lux Comprehension). The mean value for comprehension recorded when subjects were exposed to ‘normal Office light’ is closest to the lowest mean value for comprehension value than to the highest with a mean value of comprehension = 36.67 (at NOL 460 Lux Comprehension).

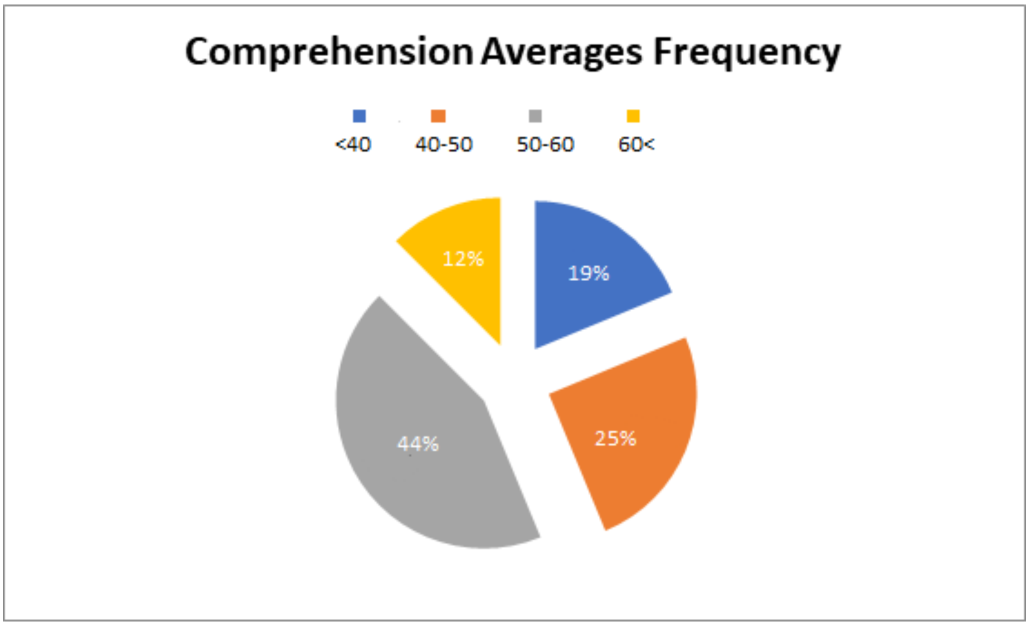

Figure 33 - CA Frequency

In terms of frequency, the majority (44%) of mean values belong to the 50-60 interval, whereas the least frequent values (12%) belong to the >60 intervals. Comprehension means values yielded the most homogenous frequency distribution with none of the intervals covering more than 50% of the total (Figure 33).

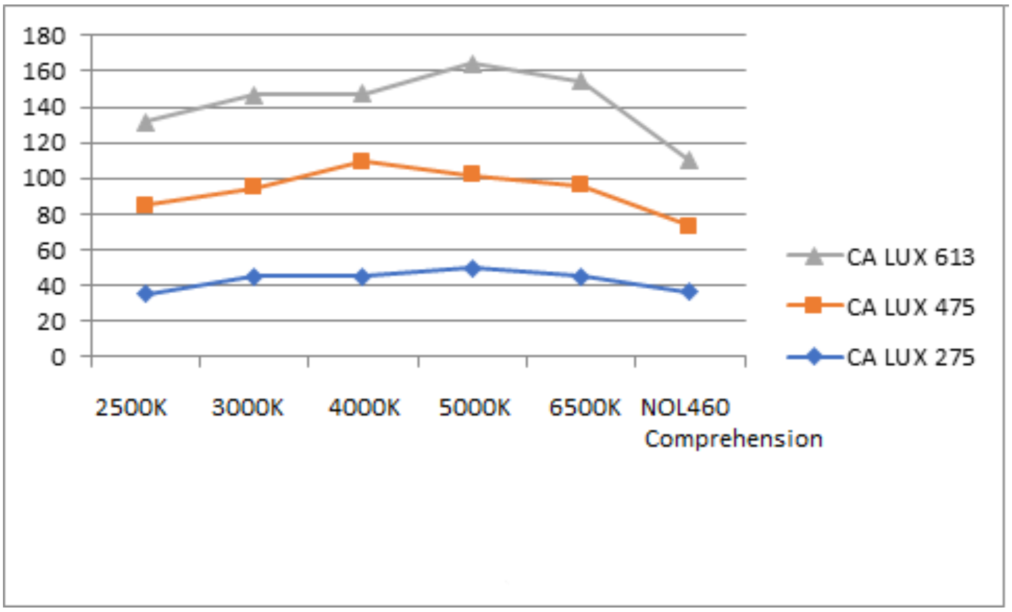

Figure 34 - CA 275 Lux, 475 Lux, and 613 Lux comparative values

The highest average value for comprehension at 275 Lux was recorded for 5000K and the lowest for 2500K (Figure 34). The mean value for reading comprehension for 'normal Office light' was closest to the lowest reading comprehension mean value at 275 Lux. A more homogenous distribution was recorded for reading comprehension mean value at 475 Lux with two equal averages for 2500K and 3000K, and two very close values for 5000K and 6500K. The highest reading comprehension mean value at 475 Lux was recorded at 4000K and the reading comprehension mean value for 'normal office light' was lower than all other values at 475 Lux. The highest reading comprehension mean value at 613 Lux was recorded for 5000K, closely followed by 6500K. The 'normal office light' reading comprehension mean value ranged lowest compared to the values in the distribution at 613 Lux.

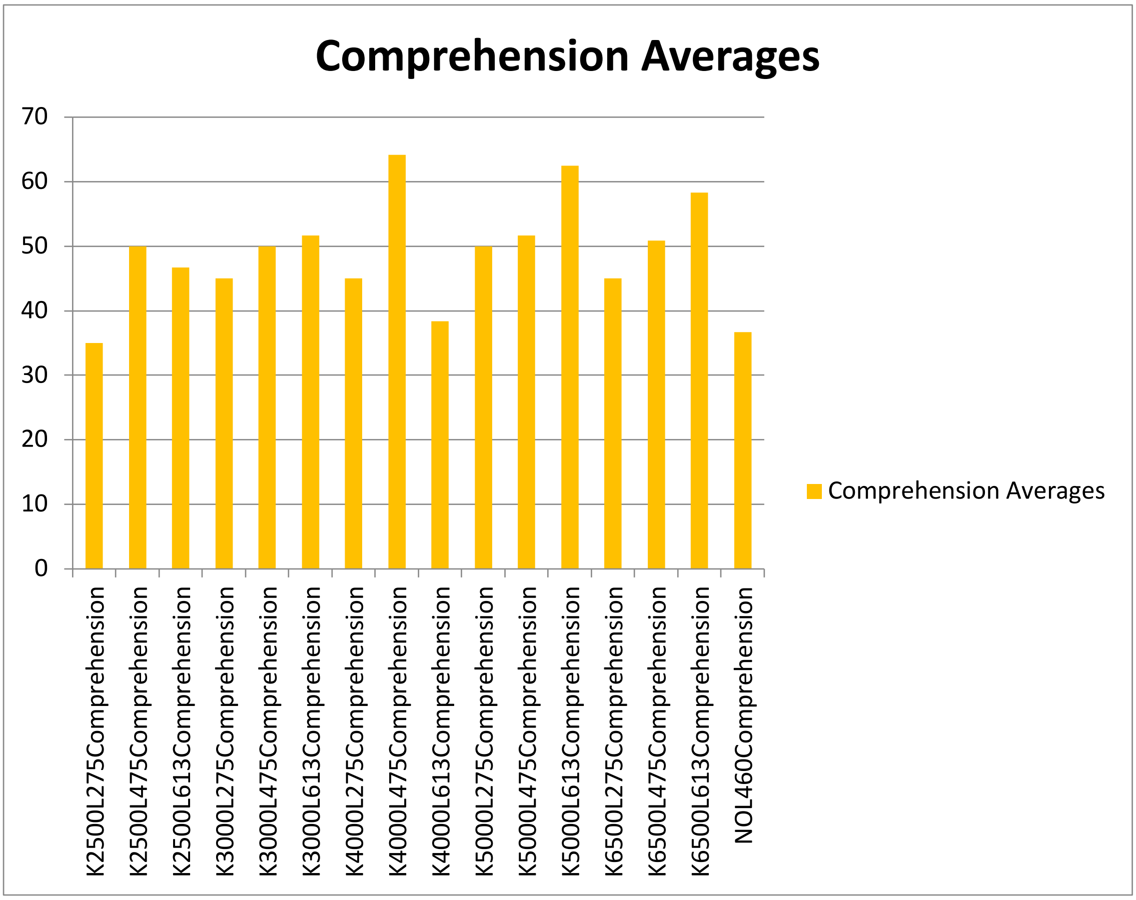

Figure 35 - Overall CA comparative values

For 'comprehension' the highest values were recorded at 4000K 475 Lux, 5000K 613 Lux, and 6500K 613 Lux. The reading comprehension mean value recorded at 'normal office light' was lower than any of these (Figure 35).

2.4 Descriptive and inferential statistical analysis

In addition to the analysis described above the data was also analysed to test the research hypotheses considered in the current study. The hypotheses (null and alternative) are as follows:

There is no statistically significant relationship between:
$H_0$1: colour temperature and alertness.
$H_0$2: colour temperature and reading speed.
$H_0$3: colour temperature and comprehension.
$H_0$4: illuminance and alertness.
$H_0$5: illuminance and reading speed.
$H_0$6: illuminance and comprehension.

The alternative hypotheses stated that there is a statistically significant relationship between the pairs of variables considered in the null hypotheses.
The data collection process entailed recording a score for each of the three dependent variables: alertness, reading speed, and comprehension for a context defined by a specific level of kelvin (K) and a specific number of Lux (lx) simultaneously. For this reason, conducting the statistical analysis necessary to test the research hypotheses had to be preceded by a process of reorganizing data which could allow observing the effect of the variance of one variable of interest (K or lx) while maintaining the other variable of interest (K or Lux) stable. For this purpose, the data was organised into the following variables to consider the variance in K while maintaining the Lux stable: alertnessL275, alertnessL475, alertnessL613, speedL275, speedL475, speedL613, comprehensionL275, comprehensionL475, and comprehensionL613. Subsequently, the data was organized into the following variables to maintain the K stable while considering the effect of the variance in Lux: alertnessK2500, alertness3000K, alertnessK4000, alertness5000K, alertnessK6500, speedK2500, speed3000K, speedK4000, speed5000K, speedK6500, comprehensionK2500, comprehension3000K, comprehensionK4000, comprehension5000K, comprehensionK6500.

a) Descriptive statistics

Two sets of samples were taken in the study, but each under different conditions. The first sample consisted of six participants who were evaluated descriptively using Excel, each being tested under five Kelvin temperatures (2500 K, 3000 K, 4000 K, 5000 K, 6500 K) in addition to a standard lighting of 6500 K office lighting. The second sample included 30 participants and was evaluated with SPSS, where each of them was subjected to 15 tests at 5 Kelvin levels, and 3 brightness levels in the range of (275,765 and 613 lux) in addition to the office lighting. In the table of 150 tests, aggregated data for thirty participants was collected at a constant brightness of 275 lux and a Kelvin parameter that was changed between five degrees giving 30*5= 150 tests (table 7). The aggregation for the table of 90 tests (table 6) involved a constant kelvin temperature parameter of 2500 K across thirty participants and three other brightness parameter levels giving a total of thirty multiplied by three equaling ninety tests.

After the data was organized for statistical analysis descriptive statistics were produced to observe the distribution of the data. The descriptive statistical analyses were conducted separately for the two categories of variables (i.e., the ones which accounted for variance in K and the ones which accounted for variance in Lux). The key results are summarised in the next table.

Statistics

	N							
	Valid	Missing	Mean	Median	Mode	Std. Deviation	Variance	Range
K	150	0	4200.00	4000.00	2500[a]	1440.078	2073825.503	4000
alertnessL275	150	0	5.59	6.00	5	1.182	1.397	6
alertnessL475	150	0	4.73	5.00	5	1.123	1.260	6
alertnessL613	150	0	4.47	5.00	5	1.133	1.284	6
speedL275	150	0	161.4933	140.0000	96.00	88.89000	7901.433	612.00
speedL475	150	0	139.0533	106.5000	99.00	71.56888	5122.105	324.00
speedL613	150	0	126.0467	121.5000	96.00	42.01172	1764.984	221.00
comprehensionL275	150	0	44.0000	50.0000	50.00	29.63424	878.188	100.00
comprehensionL475	150	0	53.3333	50.0000	50.00	26.17486	685.123	100.00
comprehensionL613	150	0	51.5000	50.0000	25.00	30.40967	924.748	100.00

a. Multiple modes exist. The smallest value is shown

Table 6 - Descriptive statistics for variables recording variance

The descriptive statistics for the variables are presented above. It is noteworthy that the highest variability in alertness is recorded at Lux= 275, with a standard deviation of 1.182, which is similar to the variability in speed (*SD*=88.89). The highest mean for alertness is found at the same Lux level, with an average of 5.59. It is essential to note that higher scores on the alertness variable indicate lower levels of alertness, as this variable is measured on the KSS scale (1- extremely alert, 9- very sleepy). The lowest mean for this variable is found at Lux=613, with an average of 4.47. For comprehension, the highest variability is recorded at Lux= 613, with a standard deviation of 30.41. The highest mean for this variable is observed at Lux=475, with an average of 53.33.

Statistics

	N		Mean	Median	Mode	Std. Deviation	Variance	Range
	Valid	Missing						
L	90	60	454.3333	475.0000	275.00[a]	139.53695	19470.562	338.00
alertnessK2500	90	60	5.2556	5.0000	5.00	1.45773	2.125	7.00
alertnessK3000	90	60	5.0556	5.0000	5.00	1.08474	1.177	6.00
alertnessK4000	90	60	5.0444	5.0000	5.00	.94704	.897	6.00
alertnessK5000	90	60	4.8111	5.0000	5.00	1.12074	1.256	6.00
alertnessK6500	90	60	4.4778	4.5000	5.00	1.40006	1.960	6.00
speedK2500	90	60	121.2222	108.5000	99.00	40.37264	1629.950	223.00
speedK3000	90	60	131.6111	125.0000	120.00[a]	39.76411	1581.184	213.00
speedK4000	90	60	172.1000	135.5000	73.00	107.12264	11475.260	603.00
speedK5000	90	60	115.5889	104.0000	96.00	45.89286	2106.155	228.00
speedK6500	90	60	170.4667	144.0000	96.00	77.86551	6063.038	320.00
comprehensionK2500	90	60	43.8889	50.0000	25.00	28.86211	833.021	100.00
comprehensionK3000	90	60	48.8889	50.0000	25.00	30.88378	953.808	100.00
comprehensionK4000	90	60	49.1667	50.0000	50.00	28.15736	792.837	100.00
comprehensionK5000	90	60	54.7222	50.0000	25.00[a]	29.95653	897.394	100.00
comprehensionK6500	90	60	51.3889	50.0000	50.00	26.59547	707.319	100.00

a. Multiple modes exist. The smallest value is shown

Table 7 - Descriptive statistics for variables recording variance in Lux

For alertness measured depending on the variation in Lux, it was observed that the highest variation corresponded to K=2500 (*SD*=1.46). The highest variation in reading speed was noted for K=4000 (*SD*=107.12), whereas for comprehension the highest variation was recorded for K=3000 (*SD*= 30.88). The lowest mean values were recorded for alertness at K=6500 (*M*=4.48), and the highest means were recorded for reading speed at K=6500 (*SD*=170.47) and for comprehension at K=5000 (*M*=54.67).

b) Inferential statistics

Inferential statistics were conducted to test the proposed research hypotheses.

1) **Hypothesis 1: There is no statistically significant relationship between colour temperature and alertness.**

Correlations

		K	alertnessL275	alertnessL475	alertnessL613
K	Pearson Correlation	1	-.017	-.306**	-.368**
	Sig. (2-tailed)		.837	.000	.000
	N	150	150	150	150
alertnessL275	Pearson Correlation	-.017	1	.437**	.158
	Sig. (2-tailed)	.837		.000	.054
	N	150	150	150	150
alertnessL475	Pearson Correlation	-.306**	.437**	1	.344**
	Sig. (2-tailed)	.000	.000		.000
	N	150	150	150	150
alertnessL613	Pearson Correlation	-.368**	.158	.344**	1
	Sig. (2-tailed)	.000	.054	.000	
	N	150	150	150	150

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

Table 8 Correlation analysis to test the relationship between colour temperature and alertness

To determine whether a statistically meaningful relationship exists between correlating factors i.e., correlated colour temperature (CCT) and alertness, correlation analysis was performed across different illuminance levels. The data presented in the table 9 show that a statistically significant negative correlation between CCA and alertness exists at 475 Lux (p=0.01) and 613 Lux (p=0.01) illuminance levels. Since higher KSS scores correspond to lower alertness (i.e., more sleepiness), this relationship is a reverse with KSS and CCT. It is hypothesized that the increment in CCT will lead to improved alertness at the stated illuminance levels therefore, the null hypothesis is accepted for Lux= 475 and Lux= 613. With regard to Lux=275, the hypothesis testing discloses a p value of 0.84 (p=0.84) which imply that CCT has no statistically significant relationship with alertness at this low illuminance level.

2) **Hypothesis 2: There is no statistically significant relationship between colour temperature and reading speed.**

Correlations

		K	speedL275	speedL475	speedL613
K	Pearson Correlation	1	-.035	.607**	-.099
	Sig. (2-tailed)		.667	.000	.229
	N	150	150	150	150
speedL275	Pearson Correlation	-.035	1	-.137	.224**
	Sig. (2-tailed)	.667		.096	.006
	N	150	150	150	150
speedL475	Pearson Correlation	.607**	-.137	1	.310**
	Sig. (2-tailed)	.000	.096		.000
	N	150	150	150	150
speedL613	Pearson Correlation	-.099	.224**	.310**	1
	Sig. (2-tailed)	.229	.006	.000	
	N	150	150	150	150

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

Table 9 - Correlation analysis to test the relationship between colour temperature and reading speed

According to the results presented in Table 19, there is a statistically significant relationship only between colour temperature (K) and reading speed for the scores recorded at Lux= 475 (p=0.001). For the other two circumstances Lux=275 and Lux=613 respectively the null hypothesis could not be rejected.

3) **Hypothesis 3: There is no statistically significant relationship between colour temperature and comprehension.**

Correlations

		K	comprehensionL275	comprehensionL475	comprehensionL613
K	Pearson Correlation	1	.099	.002	.162*
	Sig. (2-tailed)		.228	.978	.048
	N	150	150	150	150
comprehensionL275	Pearson Correlation	.099	1	.307**	.359**
	Sig. (2-tailed)	.228		.000	.000
	N	150	150	150	150
comprehensionL475	Pearson Correlation	.002	.307**	1	.173*
	Sig. (2-tailed)	.978	.000		.034
	N	150	150	150	150
comprehensionL613	Pearson Correlation	.162*	.359**	.173*	1
	Sig. (2-tailed)	.048	.000	.034	
	N	150	150	150	150

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

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

Table 10- Correlation analysis to test the relationship between colour temperature and comprehension.

The results of the correlation analysis indicate that there is a statistically significant relationship (p=0.048) between K and comprehension only for the scores recorded at Lux=613. For the other two contexts (Lux= 275 and Lux=475 respectively) the null hypothesis cannot be rejected (p=0.23 and p=0.98).

4) **Hypothesis 4: There is no statistically significant relationship between illuminance and alertness.**

Correlations

		L	alertnessK2500	alertnessK3000	alertnessK4000	alertnessK5000	alertnessK6500
L	Pearson Correlation	1	-.422**	-.046	-.308**	-.532**	-.588**
	Sig. (2-tailed)		.000	.666	.003	.000	.000
	N	90	90	90	90	90	90
alertnessK2500	Pearson Correlation	-.422**	1	.467**	.423**	.381**	.490**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	90	90	90	90	90	90
alertnessK3000	Pearson Correlation	-.046	.467**	1	.501**	.295**	.278**
	Sig. (2-tailed)	.666	.000		.000	.005	.008
	N	90	90	90	90	90	90
alertnessK4000	Pearson Correlation	-.308**	.423**	.501**	1	.516**	.535**
	Sig. (2-tailed)	.003	.000	.000		.000	.000
	N	90	90	90	90	90	90
alertnessK5000	Pearson Correlation	-.532**	.381**	.295**	.516**	1	.660**
	Sig. (2-tailed)	.000	.000	.005	.000		.000
	N	90	90	90	90	90	90
alertnessK6500	Pearson Correlation	-.588**	.490**	.278**	.535**	.660**	1
	Sig. (2-tailed)	.000	.000	.008	.000	.000	
	N	90	90	90	90	90	90

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

Table 11 - Correlation analysis to test the relationship between illuminance and alertness

The analysis of correlations between illuminance and alertness levels revealed that there are statistically significant negative correlations for K=2500 (p=.001), K=4000 (p=.01), K=5000 (p=.01), and K=6500 (p=.01). As mentioned previously the scores for alertness are reversed in the sense that a higher score of this variable indicates a higher level of sleepiness. For this reason, the negative correlation with sleepiness can be interpreted as a positive correlation with alertness. For the four cases presented above the null hypothesis can be confirmed. It is only in the context of K=3000 that the null hypothesis could not be rejected.

5) **Hypothesis 5: There is no statistically significant relationship between illuminance and reading speed**

		L	speedK2500	speedK3000	speedK4000	speedK5000	speedK6500
L	Pearson Correlation	1	.408**	-.466**	-.602**	-.329**	.105
	Sig. (2-tailed)		.000	.000	.000	.002	.324
	N	90	90	90	90	90	90
speedK2500	Pearson Correlation	.408**	1	.315**	-.079	.311**	.025
	Sig. (2-tailed)	.000		.002	.458	.003	.819
	N	90	90	90	90	90	90
speedK3000	Pearson Correlation	-.466**	.315**	1	.444**	.627**	.127
	Sig. (2-tailed)	.000	.002		.000	.000	.231
	N	90	90	90	90	90	90
speedK4000	Pearson Correlation	-.602**	-.079	.444**	1	.339**	-.334**
	Sig. (2-tailed)	.000	.458	.000		.001	.001
	N	90	90	90	90	90	90
speedK5000	Pearson Correlation	-.329**	.311**	.627**	.339**	1	.136
	Sig. (2-tailed)	.002	.003	.000	.001		.200
	N	90	90	90	90	90	90
speedK6500	Pearson Correlation	.105	.025	.127	-.334**	.136	1
	Sig. (2-tailed)	.324	.819	.231	.001	.200	
	N	90	90	90	90	90	90

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

Table 12 - Correlation analysis to test the relationship between illuminance and reading speed

Illuminance and reading speed proved to be positively correlated for K=2500 (p=0.01) and negatively correlated for K=3000 (p=0.01), K=4000 (p=0.01), and K=5000 (p=0.01). For K=6500 the null hypothesis cannot be rejected and therefore a statistically significant relationship between illuminance and reading speed cannot be confirmed.

6) **Hypothesis 6: There is no statistically significant relationship between illuminance and comprehension.**

		L	comprehensionK2500	comprehensionK3000	comprehensionK4000	comprehensionK5000	comprehensionK6500
L	Pearson Correlation	1	.181	.091	-.057	.163	.203
	Sig. (2-tailed)		.088	.395	.595	.125	.055
	N	90	90	90	90	90	90
comprehensionK2500	Pearson Correlation	.181	1	.560**	.374**	.383**	.121
	Sig. (2-tailed)	.088		.000	.000	.000	.256
	N	90	90	90	90	90	90
comprehensionK3000	Pearson Correlation	.091	.560**	1	.322**	.325**	.070
	Sig. (2-tailed)	.395	.000		.002	.002	.510
	N	90	90	90	90	90	90
comprehensionK4000	Pearson Correlation	-.057	.374**	.322**	1	.313**	.133
	Sig. (2-tailed)	.595	.000	.002		.003	.212
	N	90	90	90	90	90	90
comprehensionK5000	Pearson Correlation	.163	.383**	.325**	.313**	1	.238*
	Sig. (2-tailed)	.125	.000	.002	.003		.024
	N	90	90	90	90	90	90
comprehensionK6500	Pearson Correlation	.203	.121	.070	.133	.238*	1
	Sig. (2-tailed)	.055	.256	.510	.212	.024	
	N	90	90	90	90	90	90

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

Table 13 - Correlation analysis to test the relationship between illuminance and comprehension.

The results could not prove that there is a statistically significant relationship between illuminance and comprehension in none of the five contexts of the study.

2.5 Analysis

The results of the data analysis are summarised in the table below:

Hypothesis	Lux=275	Lux=475	Lux=613	-	-
(1) colour temperature (K) and alertness	Correlation could not be confirmed	Positive correlation	Positive correlation	-	-
(2) colour temperature and reading speed	Correlation could not be confirmed	Positive correlation	Correlation could not be confirmed	-	-
(3) colour temperature and comprehension	Correlation could not be confirmed	Correlation could not be confirmed	Positive correlation	-	-
	K=2500	K=3000	K=4000	K=5000	K=6500
(4) illuminance and alertness	Positive correlation	Correlation could not be confirmed	Positive correlation	Positive correlation	Positive correlation
(5) illuminance and reading speed	Positive correlation	Negative correlation	Negative correlation	Negative correlation	Correlation could not be confirmed
(6) illuminance and comprehension	Correlation could not be confirmed	Correlation could not be confirmed	Correlation could not be confirmed	Correlation could not be confirmed	Correlation could not be confirmed

Table 14- Results of hypotheses testing

As it can be noted that the majority of the research hypotheses were supported to identify statistically significant relationships between the variables of the study. It was supported that colour temperature is correlated with the level of alertness, reading speed, and level of comprehension. This suggests that controlling the level of K can have an impact on the level of students' achievement. However, it is important to note that no correlations were recorded between K and the three indicators in the context of Lux=275. Moreover, reading speed demonstrated a positive correlation with K only for Lux=475, whereas reading comprehension indicated a positive correlation with K only for Lux=613. Alertness was positively correlated with K for both Lux=475 and Lux=613. These results suggest that decision-makers may need to consider these conditions when establishing the lighting conditions to provide more effective learning environments. For instance, variations in K can be used at Lux=475 to prompt educators' and students' alertness and reading speed. However, when the desired result is to enhance alertness and comprehension, the variations in K need to be managed in the context of Lux=613.

Illuminance also proved to be positively correlated with alertness in the context of four colour temperatures levels: K=2500, K=4000, K=5000, and K=6500, suggesting that increasing the level of illuminance would increase the level of alertness. Reading speed was also correlated with Illuminance, however, it was only for K=2500 that this correlation proved to be positive. These findings suggest that improving both alertness and reading speed by controlling only the level of illuminance, can be achieved for a CCT of K=2500.

The results obtained are consistent with literature that confirm that colour temperature can influence alertness (Rautkyla et al., 2010) and that illuminance can influence comprehension (Rautkyla et al., 2010). However, the results of the current study exceed these findings and indicate a relevant (and statistically significant) relationship between colour temperature and all three educational attainment indicators considered as well as between illuminance and two of these indicators (alertness and reading speed). These results are consistent with studies that indicate that dynamic lighting is the most effective approach for achieving higher academic performance (Barkmann et al., 2012, Sleegers et al, 2012; Zhu et al, 2017). Therefore, it becomes evident that an effective approach to using lighting to enhance students' academic performance is altering lighting conditions according to the educational objectives.

1.4 Summary of Results

This chapter has clarified the impact of CCT on the KSS scores of alertness, reading speed, and comprehension. Both individual performance and collective performance scores were examined, and changes in scores, when compared to baseline measurements, have been analysed also. To summarise, we have the following three findings:

1. Concerning levels of alertness (as measured by f the KSS test), the CCT had no noticeable impact. However, the presence of an outlier in the upper half of the scoring may have had an impact on this.
2. With regards to reading speed, CCT appeared to have a modest impact, with 4,000K being a light setting in which the majority of our participants demonstrated minor improvements in reading speed.
3. Results for comprehension scores and their relationship with CCT appeared most promising. When the CCT increased, improvements in comprehension scores increased too. These improvements were more obvious at a CCT of 5,000K.

The results presented earlier suggest that CCT may have a significant impact on reading speed and comprehension. The highest improvements in comprehension scores were seen at a CCT of 5,000K, while reading speed showed a modest improvement at the 4,000K setting.

1.5 Analysis and Discussion

The primary research question that this research intended to answer was namely, 'does CCT influence students' reading speed and comprehension'. It was hypothesised that a positive influence on students' performance could be derived from the manipulation of light quality - in this case, the temperature of the lighting. Students' performance was monitored using three distinct constructs: alertness levels, reading speed, and levels of comprehension. The previous chapter provided insight into the impact of lighting on academic performance. This chapter will now seek to expand upon these findings and explore what they mean, and where this may lead us in the future. The findings addressed above will be placed into the context of the research questions and hypotheses that were outlined at the outset of this study. We will also consider the strengths and limitations of this research and explore directions for future studies into this area to consider.

1.6 Discussion of the strengths and limitations of the current study

Before extrapolating the implications of this study's results, it is prudent to present the strengths and limitations of the current study. This study has responded to a critical gap in the literature regarding the use of CCT settings and corresponding improvements in academic performance (Barkmann et al., 2012).

Methodologically speaking, the design of this study has several strengths. The researcher created a controlled environment in which to conduct the experiments, thereby reducing the potential for confounding variables (Creswell, 2013). Furthermore, the researcher developed a clear, strict protocol for the study's procedures. The calibrated lighting temperature within the laboratory environment also helped to maximize the trustworthiness of the results.

However, there are some limitations to this study. The participants took tests at each warmth setting during their hour as a participant in the experimental laboratory that was used for this study. This however may have caused them to improve in the tasks being measured as they gained more practice at these tasks (test-retest bias) (Campbell and Stanley, 2015). Ideally, participants would be grouped and matched and randomly allocated to sit in just one lighting condition, and these 'CCT groups' could be analysed accordingly. However, such a design, although scientifically stronger, is practically difficult to achieve in a setting where time, access to participants, and research funding are scarce (Lewis-Fernandez et al., 2016).
However, the key limitation of this research relates to the sample size. Only six participants took part in this research study. Such a small sample size when using a quantitative approach precludes the use of inferential statistics from which to build a solid scientific case of evidence (Cohen, 1992). Instead, the only analysis that was possible to be carried out is descriptive statistics.

Whilst acknowledging the limitations of this small sample size - often unavoidable when constrained by time or finance issues - this study can be characterized as an exploratory study examining the areas of interest outlined previously. It might be a first step towards the development of greater knowledge about this potentially beneficial topic.

1.7 Analysis and Discussion of the Results

Regarding alertness levels, no significant differences were found across different CCT variations. This could be due to the small sample size of the experiment. Only five of the six participants showed no change or reduced scores on the KSS when the CCT was 5,000K, suggesting increased alertness. A larger sample size may reveal more meaningful results, as one participant had different results. This should be further investigated.

Regarding reading speed, the descriptive analysis identified 4,000K lighting temperature as having the greatest positive effect. Again, the results are small in immediate magnitude - at a CCT of 4,000K, there was a mean improvement in reading speed of 8.8 words/minute compared to results taken at baseline measurement. Once more, however, we must caveat these findings regarding the sample size, and an observation that these results were influenced by the scores of an outlier score. The majority of participants however did stabilise or improve their reading speed at a CCT of 4,000K. These results certainly provide the impetus and scope for future investigation into this area.

Finally, the results indicated that as CCT increased, there was an increase in students' comprehension scores. This improvement continued within settings with a CCT of 5,000K, before tapering off at 6,500K. These findings were of interest for several reasons. Firstly, these were the only findings in this study that indicated the effect of CCT on reading comprehension as an indicator of academic performance. Secondly, these results were consistent and were not influenced by an outlier, with a relatively low level of variability. Thirdly, although reading speed was found to be best impacted upon at a lower lighting temperature of 4,000K, the identification of a temperature of

5,000K as being important to comprehension backs up the more conservative findings relating to levels of alertness and KSS scores that were mentioned above.

The results outlined earlier point towards there indeed being some positive impact of lighting on academic performance. The most promising results concern the relationship between lighting temperature and comprehension. This is encouraging because comprehension is a core academic indicator of success (Freund et al., 2014), and finding environmental conditions that develop students' performance in this field is crucial. The current results support that 5,000K is the optimal condition or as Winterbottom and Wilkins (2009) described the 'caffeine shot' that improves performance as indicated by the KSS results. Nevertheless, there needs to conduct more research to understand this relationship in greater detail. Winterbottom and Wilkins (2009) when describing the 5000K condition as a "caffeine-shot" improvement call for discussing whether such advantages blossom under this lighting condition are durable, or are just short-lived. This raises important issues not only about the temporal aspect, but the sustainability aspect as well. It calls for longitudinal studies on these effects on academic performance. Furthermore, while this research explains how both the intensity (lux) and spectral characteristics (colour temperature) are critical in developing lighting, it gives most attention to the brightness, and the colour temperature and does not work with the spectral power distribution which is necessary to evaluate the aspects of light that affect visual and non-visual such as circadian rhythms. It is indefinite without SPD which clarifies the correlation between the optimal lighting design and the spectral information. More importantly, it is necessary in the future to use SPD evaluation to evaluate the influences of lighting on academic activity in the short- and long-term period.

VIII. Discussions

The researcher conducted two experiments to examine the effects of lighting characteristics on the learning outcomes of students, with a focus on cognition and alertness. The research was motivated by previous work from Bellia et al. (2013) who suggested that lighting quality is an important factor in educational environments, as it affects people's performance, mood, and circadian rhythm. The experiments demonstrated that daylight and electric light have different spectral power distributions and correlated colour temperatures, which are affected by indoor and outdoor reflectance, and by the percentages of the visual field occupied by windows, sky, and internal and external surfaces. These results provide valuable information for lighting designers to better evaluate lighting quality in educational environments and its implications on human health and wellbeing. A good lighting design should consider both the intensity and spectral characteristics of the light in order to create an environment that is both comfortable and conducive to learning.

The second experiment aimed to assess the combined effects the colour temperature and brightness levels on students' academic performance. The experiments for the brightness levels and the colour temperature were done separately, but the results for which were analysed together. The rationale behind this experimental approach was that it would be the only way for the researcher to ascertain the impact of lighting temperature when brightness is constant as opposed to the impact of different lighting temperatures when brightness levels are varying. This also allowed the researcher to get a more complete picture of the impact of colour temperature on the reading speed and comprehension of the students.

This approach was adopted from previous studies conducted with similar objectives, such as Park et al. (2013) and Feltrin et al. (2020) which were conducted to explore the effect of some light characteristics on certain cognitive processes. The justification for the application of this methodological approach is to properly isolate and combine the results and findings for each, depending on the aims and objectives of the study.

In Galetzka et al.'s (2012) study, it was argued that keeping the lighting conditions natural (i.e., as close to the characteristics of daylight or sunlight as possible), is an effective way to boost students' concentration. Concentration, in turn, enables the students to follow their lessons, and learn more effectively. This is where the inference that students who study under optimal lighting conditions exhibit more positive learning outcomes than those who do so under suboptimal lighting conditions comes from.

In terms of the colour temperature, there is still an ongoing debate as to how warm or cool in terms of Kelvin the sun emits during a typical day. the sun emits during a typical day. Due to these variations, it would be recommended to describe this measure using a range of K values, instead of a precise number. The colour temperature of the sun on a typical clear day should be anywhere between 5000K to 6500K. The most frequently cited colour temperature of sunlight is 5500K. In the present study, the student's response to colour temperatures in terms of their cognition and alertness was measured at varying levels, namely, at a baseline, 6500K, 5000K, 4000K, 3000K, and then 2500K.

A summary of the results of the KSS performance can be found in Figure 1. In order to understand the meaning of numbers and figures, a background on the KSS scoring system is needed. The Karolinska Sleepiness Scale's scoring system is inverted, which means that the lower an individual's score is, he is judged to be more alert. Therefore, to confirm the research hypothesis that a light colour temperature is within the optimal range of 5000K and 6500K the results and findings should show a series of low or a declining set of KSS scores.

It is also worth noting that the experiments were conducted under a series of colour temperature levels. The most important number to look at in this case would be the mean KSS scores for every light colour temperature rating. At 5000K, the mean KSS score for all participants was 3; at 4000K, the mean KSS score was 4; at 6500K, the mean KSS score was 3.5. What this means is that if the KSS scores (i.e., collective or mean scores) alone would be the basis of deciding which colour temperature level can be considered optimal in terms of maintaining a high level of awareness. In the present study, it would be the 5000K level.

The results and findings that revealed the optimal level of colour temperature, in Kelvins, for students in an indoor setting varies significantly. The lower end of the range is 5000K. The results and findings of the present study are rather surprising, because it shows that the optimal level of colour temperature can be found at the lower end of that range.

Within the context of the present study, the lowest possible mean scores (in the KSS) were obtained in lighting conditions that were between 5000K and 6500K. This confirms what the previously published studies are suggesting about the ideal colour temperature rating for indoor lighting, within the context of the education system.

There was a higher level of variability in the participants' mean KSS scores under the lighting conditions where the colour temperature was set to between 2500K and 6000K. This result suggests that these colour temperature levels are not optimal for indoor classroom settings, as the KSS scores were higher, meaning the students were less alert. However, it should be noted that the outlier value caused by the scores of the second participant had a significant impact on the mean scores because of the small sample size used in this study.

The researcher found that the actual KSS scores of the participants (excluding scores of participants 2) under different light colour temperature settings would have been much closer to the baseline—KSS scores under the 5000K to 6500K light colour temperature settings.

It is worth noting that for the second experiment, the brightness of the indoor lighting was measured at three different levels, namely, 275, 475, and 613 Lux (which is equivalent to Lumen Per Square Meter).

In the second experiment, the researcher conducted a correlational statistical analysis between the KSS test scores, the Lux ratings, and the Colour Temperature ratings. The results revealed that there is a negative correlation between Colour Temperature and KSS mean scores, however this correlation was not statistically significant. What is interesting is that the Brightness level (in terms of Lux) was found to have a strong negative correlation (-0.766) with the KSS mean scores as well.

These findings contradict the established relationship between colour temperature and alertness and cognitive performance in previously published studies. For example, Motamedzadeh, M et al. (2018) concluded that there is a statistically significant relationship between the colour temperature rating and the alertness level of their students. They also measured alertness using the Karolinska Sleepiness Scale. However, Motamedzadeh did not test the relationship between brightness and alertness and cognitive performance.

In Karin's (2018) study, they focused on the relationship between brightness and alertness, and cognitive performance. Karin et al. (2018) concluded that exposure to intense light (of at least one hour) does not systematically benefit alertness and cognitive performance (the specific cognitive performance they tested was executive functioning). This generally goes against the findings of the present study—because it was found here that brightness ratings (in terms of Lux or Lumens per square meter) had a negative relationship with alertness and cognitive performance.

For reading speed and reading comprehension, most of the findings suggest that there is no statistically significant correlation between these variables and illuminance and colour temperature. This set of findings also goes mostly against the results and findings in the previously published studies. In Morrice et al.'s (2021) study, for example, they concluded that reading outcomes (e.g., speed and comprehension) do increase when individuals get subjected to optimal or improved lighting conditions, specifically with higher levels of illuminance and colour temperature.

In fact, this study's results diverge from the earlier findings probably because of the use of small sample size, sensitivity to outliers, and the independent assessment of brightness and colour temperature effects. Such environmental considerations as surface reflectance and baseline lighting as well as participant's variations such as circadian rhythms and light adaptation among others could similarly be contributory. This research, contrary to others, established a stronger association between brightness (Lux) and alertness in relation to the Lux parameter, though the effects of colour temperature on brightness were not confirmed statistically significant. Apart from that, exclusive use of the Karolinska sleepiness scale (KSS) may be diminishing the effects of other aspects of light on sleepiness. Such discrepancies necessitate larger and more controlled trials with detailed parameters to determine the relationship between lighting characteristics and cognition.

1. Essential Takeaways

The first idea that becomes evident after a thorough analysis of the findings presented in this dissertation is that lighting temperatures could affect students' cognitive functioning. The level of alertness depends on the strength of the suggested lighting scheme and the CCTs picked by educators in the process of designing the learning environment. It is crucial to realize that students might read more quicker and comprehend the text better under conditions where the learning environment is brightly lit. Poor lighting in classrooms causes unnecessary pauses during the learning process and negatively affect the students' cognitive abilities to a certain extent. The results of the current study reveal that brighter lighting colours affect students' cognitive activity positively and aid them to read and comprehend the new material quickly irrespective of the subject being studied or the instructor's approach to presenting new information.

One more problem that could be encountered when testing the effectiveness of lighting temperatures is the incorrect choice of lighting that could diminish the positive effects achieved previously. For example, if there are cool-white lights, the educator should be careful because such fluorescent lighting could influence negatively the students' ability to read or comprehend. This idea is confirmed by the findings achieved in the current experiments because many learners would have trouble reading both when the light condition is too bright or too low levels. Academic performance could be supported with the help of lighting temperatures from 3000K to 5000K, depending on the academic objectives of the learner.

The third essential takeaway is that according to the current research results, optimal academic outcomes might be accomplished with lighting temperatures ranging from 475Lux to 613Lux. Nevertheless, these findings should not be perceived as a standard measure of optimal lighting that affects positively students' performance because the adjustment of lighting temperature should be made according to learners' goals. In other words, all students learn at their own pace using a wide variety of learning styles, which makes it hard for researchers to agree on universal set of lighting conditions that fit all learning goals.

2. Provisional Deductions

In the future, it would be more beneficial to extend the current experiment by exploring more performance indicators that would show the extent to which the educational environment contributes to enhancing students' capabilities. The findings revealed by the current research indicated that artificial lighting should be designed as close as possible to natural daylight to stimulate the most effective outcomes in students. Even though it is not the teachers' responsibility to design the educational buildings, they may still be held liable for providing their objective feedback regarding the quality of lighting.

The current study shows that lighting temperatures similar to daylight have to be promoted as the best option because they maintain the conventional rhythm of human biological systems.

Results achieved within the framework of the current study revealed that standard fluorescent lighting cannot be considered an adequate aid to learners' academic performance and cognitive activities. The evident outcomes of using conventional fluorescent lighting are impaired task performance and a general feeling of discomfort that decreases the students' alertness levels. In other words, the fluorescent lighting had a relaxing effect on students and averted them from concentrating properly. The current research project reinforces the idea that LED lighting at certain temperatures could be utilized to help students remain alert and focused.

On the other hand, the coolest temperature that was found to be enough to motivate learners and keep their alertness intact was 6500K. It is one of the CCT levels that are the closest to the natural sunlight without pushing too much into the tones of yellow. Therefore, a productive classroom environment should benefit from 5000K lamps (at least) in order to help students to maintain their alertness during performing academic tasks in the classroom. Another important finding that should be highlighted was that warmer colour temperatures could be implemented when there would be a need for a more relaxed environment and no urgent or complex tasks assigned to students. Accordingly, the 3500K could be described as tranquil, 5000K as neutral, and 5500K (or slightly above) as ideal for improved comprehension and alertness.

The author may conclude that it would be beneficial to provide teachers with custom lighting controls allowing them to make changes to the educational setting (for example, 5500K and above would stand for "prepare" and 3500K or below would stand for "relax"). Additionally, it would be interesting to investigate the influence of the location of lights in addition to the chosen temperatures.

Further research should be conducted to examine the effect of lighting on other personal characteristics of learners, such as achievement motivation, attitudes, or other cognitive processes such as memorization. That could be achieved through the introduction of pre- and post-transition studies where fluorescent lamps would be replaced with LEDs, and the researchers would test the changes that occurred in terms of reading capability, comprehension, alertness, mood, and behaviour.

Improved lighting is a serious add-on to any learning environment, and there should be additional experiments that would shed the light on the benefits of a well-lit space.

IX. Conclusion

The previous chapter discussed the results of the present study and highlighted the areas of interest that were derived from the data. The strengths and limitations were also considered and appraised so that the reader understands accurately the results. This final chapter will sum up the entire study, illustrate the way these results may be implemented, and provide readers and researchers with proposed directions for future research.

1. First Experiment

Although small in size, this study can be characterized as an exploratory study with very promising results. As identified during the literature review of this study, the design of educational establishments plays an important role in the educational achievements of students who interact with this environment (Tanner, 2008; Galetzka *et al*., 2012). Despite this, and with the constantly developing knowledge of the psychological and physiological impacts of light and lighting on individuals (Berman *et al*., 2011; Iszo, 2001), there is limited scientific investigation on the impact of lighting on educational attainment or performance (Barkman, 2012). Most of the research has focussed more on attention span, concentration, motivation, and behaviour (Cajochen, 2005; Kuller and Wetterberg, 1993). However, the current study is the first to date to methodically examine the impact of dynamic lighting (i.e., the lighting temperature) on certain aspects of alertness, reading speed, and comprehension. Despite the exploratory nature and small sample size, the results stemming from this study might be of interest to researchers in the field, as well as to designers of the interiors of educational establishments. The following sections will elucidate further why future work is needed in the same realm of this study.

The first call must be for a replication study to be carried out - now there is a notion that the variables examined within this study - especially that of comprehension levels - can be affected by manipulating the warmth of the lighting, further replication of the study is needed to confirm the preliminary results about the impact of variations in light characteristics on students' comprehension.

However, some adjustments to the methodological procedure adopted in the study are worth noting. Firstly, during the planning phase of the research project, an a priori power analysis should be conducted to identify a sufficient sample size for conducting more inferential statistical analysis (Cohen, 1992). Secondly, future researchers may only test each participant in one lighting condition, in order to avoid any test-retest confounding bias.

On the other hand, learning within an educational setting doesn't take place within controlled experimental conditions, it can occur in chaotic and highly sensory environments (Fraser, 2015). So, it is within these environments that we must evaluate the use of different types of dynamic lighting. We must also take into account that often, the impact of lighting may need a longer time to affect students than in laboratory studies; or there may be an accumulation effect in which the longer one is exposed to certain light parameters, the impact becomes more (or less) pronounced (e.g., Keijzer *et al*., 2014). Thus, a field study examining the relationship between CCT and other variables of interest is crucial to assess this relationship in real school settings.

The results of the current study could provide suggestions for higher education leaders to conduct changes in the way university interiors are designed and the way lighting is incorporated. For example, Universities can adopt different lighting temperatures in their buildings. A CCT (5,000K) that contributes to increased comprehension (according to the results of the study) would be more useful in lecture halls where comprehending information is the key task (Palmer, 2017). Contrary, a different temperature of 4,000K, for example, can be more beneficial in another environment such as library study areas/computer zones to help students in perceiving and read new information more quickly.

whereas this study was applied among university learners, future research may examine these results to illustrate if they apply to younger age groups and prior educational levels. As more and more research are undertaken in any of the directions postulated above, the more we can begin to understand the extent of the dynamic lighting effects, and how we can maximise its positive impacts.

2. Second Experiment

In the second experiment, the researcher manipulated both the CCT and brightness levels. The purpose of doing the first and second experiments independently was to determine the influence of lighting temperature when the brightness level is constant vs. the impact of different lighting temperatures when the brightness level is dynamic.

All the research hypotheses, except one, revealed a significant statistical relationship among the variables of the study. It has been supported that colour temperature is related to respondents' concentration, reading speed, and comprehension.

This means that altering the proportion of K in an educational setting can influence the level of achievement of those susceptible to it in terms of the following educational attainment indicators investigated. Nonetheless, it should be noted that no correlations were discovered between K and the three indicators under the Lux=275 scenario. Furthermore, speed of reading provided instruction correlated positively with K only for Lux=475, while comprehension correlated positively with K only for Lux=613.

For both Lux=475 and Lux=613, alertness was positively associated with K levels. Putting these results in practical implications would be encouraging teachers to use variations in K levels Lux=475 to increase learners' awareness and linguistic competencies. If the teacher's goal is to improve students' ability to comprehend better the reading materials, changes in K should be controlled to Lux=613.

The findings are consistent with previous literature, which confirmed that light intensity and illuminance can influence vigilance and comprehension accordingly. Additionally, the research presents further new findings concerning the meaningful relationship between colour intensity and all three educational attainment indicators. As well as the statistically significant relationship between illuminance, alertness, and reading speed. In conclusion, these findings are compatible with previous research that suggested that 'dynamic lighting is the most effective solution for promoting academic achievement. Hansen et al. (2017) has found that effects of dynamic lighting on academic performance. Also, Dynamic lighting is essential for creating optimal learning environments and should be taken into consideration when designing a classroom. Similarly, Choi & Suk (2016) demonstrated the potential of using dynamic lighting to improve the performance of elementary students. Three lighting settings were tested to evaluate the impact of dynamic lighting in a learning setting.

Numerous investigations have been performed to investigate how the quality and colour of ambient illumination could either impede or increase pupils' educational achievement. Unfortunately, many classroom settings were unproductive because of their lighting systems and have been shown to cause anxiety and disturb the visual performance. Others were over-lit with extreme lighting systems and excessive daylighting.

Depending on the results of this research, it is conceivable to assume that there is a substantial link between the type of illumination provided in lectures and individual reading speed, cognition, and attentiveness. The present study indicated that values between 250 and 500 Lux result in a higher level of concentration among pupils. Students might benefit from better optical circumstances if artificial Light was limited to variations of 2500K to 5000K to help learners achieve the best learning outcomes.

Moreover, while our results revealed an improved performance in accomplishing reading tasks, the research did not include a circumstance for which the illumination was transformed to relatively low conditions.

The 5000K warmth is a superb illustration of a lighting temperature that would promote the variance in the learners' effectiveness. Language or theme sophistication, font size, pollution levels, or even just the in-house temperatures are some of the elements that should be considered in future research. The 5000 K rating approximates that of artificial lighting, which could potentially account for differences in learners' performance across students, which correlates closely with the objective of this study. As the study aimed to determine the influence of five levels of correlated colour temperature (CCT) of 2500K, 3000K, 4000K, 5000K, and 6500K on the academic performance of students in terms of their ability to stay awake, reading speed, and reading comprehension. Its recommendations can also include factors such as language or theme complexity, text clarity, ambient temperature and many more that can enhance these relationships further, the findings address the research question:

What are the impacts of different light colour temperatures on students' cognitive functions and alertness, particularly in terms of reading speed and comprehension?

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XI. Appendices

Appendix 1: The ethical approval form for the first experiment

The Secretariat
Level 11, Worsley Building
University of Leeds
Leeds, LS2 9JT
Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Amal Alkhabra

School of Design

University of Leeds

Leeds, LS2 9JT

Faculty of Arts, Humanities and Cultures Research Ethics Committee

University of Leeds

26 July 2017

Dear Amal

Title of study	**Does the temperature (colour) of lights in a learning environment effect a student's reading speed and comprehension**
Ethics reference	**LTDESN-070**

I am pleased to inform you that the above research application has been reviewed by the Faculty of Arts, Humanities and Cultures Research Ethics Committee and I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	*Version*	*Date*
LTDESN-070 Amal Alkhabra - 200999487, Light touch ethical review form	1	11/07/2017

Please notify the committee if you intend to make any amendments to the information in your ethics application as submitted at date of this approval as all changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation and other documents relating to the study, including any risk assessments. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Victoria Butterworth

Research Ethics Administrator, the Secretariat

On behalf of Dr Kevin Macnish, Chair, PVAR FREC

CC: Student's supervisor

Appendix 2: The ethical approval form for the second experiment

The Secretariat
University of Leeds
Leeds, LS2 9JT Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Amal Alkhabra

School of Design

University of Leeds

Leeds, LS2 9JT

Arts, Humanities and Cultures Faculty Research Ethics Committee

University of Leeds

17 February 2025

Dear Amal,

Title of study:	**Does the temperature (colour) of the lights in a learning environment effect a student's reading speed and comprehension**
Ethics reference:	**LTDESN-085**

I am pleased to inform you that the above application for light touch ethical review has been reviewed by a representative of the Arts, Humanities and Cultures Faculty Research Ethics Committee and, following receipt of your response to their initial comments, I can confirm a favourable ethical opinion as of the date of this letter, providing the answers to the questions in section A4 are yes. The following documentation was considered:

Document	Version	Date
LTDESN-085 Alkhabra, A - 200999487, Light touch ethical review(re-study).pdf	1	03/05/2018
LTDESN-085 researcher's response.txt (by email)	1	21/05/2018
LTDESN-085 Suitability Evaluation.docx	1	21/05/2018

Please notify the committee if you intend to make any amendments to the original research as submitted at date of this approval, including changes to recruitment methodology. All changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation, as well as other documents relating to the study. You will be given a two week notice period if your project is to be audited, there is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie

Senior Research Ethics Administrator, the Secretariat

On behalf of Prof Robert Jones, Chair, AHC FREC

CC: Professor Stephen Westland and Dr Vien Cheung

Appendix 3: Suitability Evaluation

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Faculty of Arts, Humanities and Cultures

School of Design

UNIVERSITY OF LEEDS

Suitability Evaluation

Name of research project: An Examination of the Affects of CCT on Cognition and Alertness in Students Reading Speed and Comprehension.

Lead researcher: Amal Alkhabra, University of Leeds, United Kingdom.

Before you have been officially involved in this study, it is important to assess your suitability for this study. Please read and answer the questions below:

	Yes	No
Are you blind or have a serious visual impairment uncorrected by glasses?		
Do you have any prior health conditions (e.g. epilepsy)?		
Do you have any learning difficulties (e.g. dyslexia)?		
Do you have a mental health condition (e. g. depression)?		

Name of the participant	Date	Signature
Leader researcher	Date	Signature

Appendix 4: Participant Consent Form

Faculty of Arts, Humanities and Cultures

UNIVERSITY OF LEEDS

School of Design

Participant Consent Form

Name of research project: An Examination of the Affects of CCT on Cognition and Alertness in Students Reading Speed and Comprehension.

Lead researcher: Amal Alkhabra, University of Leeds, United Kingdom.

	Add your initials next to the statement if you agree
I confirm that I have read and understand the information sheet, dated XX / XXXX, explaining the above research project. I have had the opportunity to ask questions about the project.	
I understand that my participation is voluntary and that I am free to withdraw at any time.	
I give permission for members of the research team to directly quote me (where appropriate) and to have access to my anonymised responses.	
I agree for the data collected from me to be used for the purpose of PHD study over the next four years.	
I agree to take part in the above research project. and should let Mrs. Amal Alkhabra or any member of the team know if my contact details has changed.	

Name of the participant	**Date**	**Signature**
Leader researcher	**Date**	**Signature**

Appendix 5: Participant Information Sheet

Faculty of Arts, Humanities and Cultures

UNIVERSITY OF LEEDS

School of Design

Participant Information Sheet

Name of research project: An Examination of the Affects of CCT on Cognition and Alertness in Students Reading Speed and Comprehension.

Lead researcher: Amal Alkhabra, University of Leeds, United Kingdom.

E-mail contact: sdaama@leeds.ac.uk

You are being invited to take part in the above named study. Before you decide, please take time to read the following information carefully. Please do not hesitate to ask if you have any questions or/and if there is anything that is not clear.

What is the purpose of this research?

This study examines the potential of dynamic lighting systems to boost reading performance. A number of studies have shown that variations in CCT can make a big difference to pupils' attention span, concentration, motivation and even behaviour. As a consequence, scholars are beginning to pay serious attention to the ways in which artificial lighting systems can be amended to optimise learners' performance. This study seeks to examine this phenomenon in the particular context of students' reading speed and comprehension.

Why is this research needed?

The research will generate much needed new evidence about how dynamic lighting systems boost reading performance and how they can be amended to optimise learners' performance.

Who will be involved in the research and where will the research take place?

Participants for this study will consist of 30 undergraduate and postgraduate students who have been pre-selected for this study. All testing will take place out of class hours. The setting for this study will take place in a psychophysical laboratory.

How will the research be carried out?

Karolinska Sleepiness Scale (KSS) questionnaire and printed reading tests will be the main methods used to collect information.

What will the research produce?

Briefing papers and other research papers will be created to encourage research findings' use and amend artificial lighting systems to optimise learners’ performance.

Appendix 6: Karolinska Sleepiness Scale

Faculty of Arts, Humanities and Cultures

School of Design

UNIVERSITY OF LEEDS

Name of research project: An Examination of the Affects of CCT on Cognition and Alertness in Students Reading Speed and Comprehension.

Lead researcher: Amal Alkhabra, University of Leeds, United Kingdom.

Karolinska Sleepiness Scale

The following is a list of some descriptors about how sleepy or alert you may be feeling right now. Please read them carefully and place the X next to ONE statement that best corresponds to the statement describing how you feel at the moment.

Extremely alert	
Very alert	
Alert	
Rather alert	
Neither alert nor sleepy	
Some sighs of sleepiness	
Sleepy, but no difficulty remaining awake	
Sleepy, some effort to keep alert	
Extremely sleepy, fighting sleep	

Appendix 7: The following are the results of the first experiment

First Participant (Male)			
	KSS	**Reading speed**	**Comprehension**
Base Test	5- Neither alert nor sleepy	80 Words per Minute	100 Percent
2500K	5- Neither alert nor sleepy	45 Words per Minute	100 Percent
3000K	2- Very alert	53 Words per Minute	100 Percent
4000K	5-Neither alert nor sleepy	63 Words per Minute	100 Percent
5000K	3- Alert	82 Words per Minute	100 Percent
6500K	5- Neither alert nor sleepy	38 Words per Minute	100 Percent

Second Participant (female)			
	KSS	**Reading speed**	**Comprehension**
Base Test	1- Extremely alert	66 Words per Minute	50 Percent
2500K	6-Some sighs of sleepiness	89 Words per Minute	100 Percent
3000K	5-Neither alert nor sleepy	91 Words per Minute	75 Percent
4000K	5-Neither alert nor sleepy	79 Words per Minute	100 Percent
5000K	4- Rather alert	83 Words per Minute	75 Percent
6500K	6- Some sighs of sleepiness	68 Words per Minute	75 Percent

Third Participant (female)			
	KSS	**Reading speed**	**Comprehension**
Base Test	3- Alert	111 Words per Minute	75 Percent
2500K	2- Very alert	115 Words per Minute	75 Percent
3000K	2- Very alert	80 Words per Minute	50 Percent

4000K	3- Alert	97 Words per Minute	75 Percent
5000K	2- Very alert	90 Words per Minute	100 Percent
6500K	2- Very alert	88 Words per Minute	100 Percent

Fourth Participant (Male)			
	KSS	**Reading speed**	**Comprehension**
Base Test	5- Neither alert nor sleepy	63 Words per Minute	50 Percent
2500K	5- Neither alert nor sleepy	73 Words per Minute	100 Percent
3000K	5- Neither alert nor sleepy	81 Words per Minute	75 Percent
4000K	5-Neither alert nor sleepy	66 Words per Minute	75 Percent
5000K	5- Neither alert nor sleepy	58 Words per Minute	100 Percent
6500K	5- Neither alert nor sleepy	57 Words per Minute	75 Percent

Fifth Participant (Male)			
	KSS	**Reading speed**	**Comprehension**
Base Test	3- Alert	114 Words per Minute	50 Percent
2500K	4- Rather alert	80 Words per Minute	25 Percent
3000K	5- Neither alert nor sleepy	77 Words per Minute	75 Percent
4000K	3- Alert	119 Words per Minute	50 Percent
5000K	2- Very alert	97 Words per Minute	75 Percent
6500K	1- Extremely alert	132 Words per Minute	50 Percent

Sixth Participant (female)			
	KSS	**Reading speed**	**Comprehension**
Base Test	4- Rather alert	85 Words per Minute	75 Percent
2500K	5- Neither alert nor sleepy	114 Words per Minute	75 Percent

3000K	2- Very alert	91 Words per Minute	50 Percent
4000K	3- Alert	148 Words per Minute	75 Percent
5000K	2- Very alert	103 Words per Minute	100 Percent
6500K	2- Very alert	81 Words per Minute	75 Percent

Appendix 8: The following are the results of the second experiment

Participant 1																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
		*												*		3	
												*				4	
	*			*		*		*			*				*	5	
*			*		*		*		*	*			*			6	
																7	
																8	
																9	
107	119	163	80	175	143	110	96	100	115	126	123	127	155	161	94	speed	
25	100	50	50	100	75	100	75	75	100	100	75	75	100	100	75	comprehension	

Participant 2																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
													*			2	
		*									*			*		3	
								*				*				4	
*	*			*	*										*	5	
			*				*		*	*						6	
						*										7	
																8	
																9	
177	108	213	96	172	138	112	146	76	224	95	177	152	142	196	115	speed	
75	75	75	75	50	100	75	25	75	50	75	75	100	100	50	75	comprehension	

Participant 3																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
																3	
																4	
*			*		*	*		*	*		*	*		*	*	5	
	*	*		*			*			*			*			6	
																7	
																8	
																9	
57	79	174	82	139	130	92	114	91	86	133	124	108	134	132	76	speed	
75	100	50	100	100	100	75	75	50	100	100	100	100	75	100	100	comprehension	

Participant 4																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
																3	
*	*			*							*	*	*			4	
		*	*		*	*	*	*	*					*	*	5	
										*						6	
																7	
																8	
																9	
86	63	230	122	158	87	96	135	110	158	76	100	116	97	99	81	speed	
100	75	75	50	100	50	0	50	50	50	50	75	50	75	75	50	comprehension	

Participant 5																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
	*															3	
*		*		*			*				*					4	
					*			*		*		*	*			5	
			*			*			*					*		6	
															*	7	
																8	
																9	
124	200	375	140	96	104	119	154	73	401	162	130	142	164	99	74	speed	
25	100	75	50	100	25	75	50	75	25	25	75	25	25	25	0	comprehension	

Participant 6																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
		*				*										3	
							*									4	
*	*			*	*			*		*	*		*	*		5	
			*									*				6	
									*						*	7	
																8	
																9	
247	193	283	88	58	105	70	143	76	184	120	107	70	148	97	48	speed	
50	25	100	25	25	25	50	25	50	50	25	25	75	25	50	50	comprehension	

Participant 7																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
																3	
		*														4	
	*			*	*		*	*		*				*		5	
*											*		*			6	
			*			*									*	7	
									*			*				8	
																9	
120	110	236	88	68	99	82	143	142	228	96	99	147	92	87	96	speed	
25	25	25	25	50	50	25	0	50	25	50	0	50	50	75	25	comprehension	

Participant 8																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
																3	
				*					*							4	
*	*	*			*	*	*	*		*		*	*			5	
			*								*			*		6	
																7	
															*	8	
																9	
247	119	248	96	61	87	142	126	73	385	120	135	207	164	99	95	speed	
50	100	25	75	25	50	50	50	75	0	25	50	0	25	25	0	comprehension	

Participant 9																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
	*	*		*												3	
							*			*						4	
			*		*			*	*				*			5	
*						*					*	*		*		6	
																7	
															*	8	
																9	
120	200	290	162	96	105	127	154	110	327	84	137	151	171	100	95	speed	
25	100	50	25	100	25	25	50	50	25	25	0	25	50	0	0	comprehension	

Participant 10																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
	*															3	
*				*							*					4	
		*			*		*			*		*	*	*		5	
								*	*							6	
			*			*										7	
															*	8	
																9	
124	119	228	81	96	88	168	117	107	252	162	130	142	179	97	95	speed	
25	100	50	25	75	25	0	25	25	25	25	75	25	25	50	0	comprehension	

Participant 11																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
	*															2	
																3	
*		*		*					*							4	
					*		*	*		*		*				5	
			*								*		*	*	*	6	
						*										7	
																8	
																9	
126	144	236	96	96	104	151	126	73	385	120	135	207	129	99	53	speed	
25	25	25	75	100	25	50	50	75	0	25	50	0	50	25	50	comprehension	

Participant 12																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
																3	
	*	*		*												4	
*					*	*	*	*	*	*			*			5	
			*								*	*		*	*	6	
																7	
																8	
																9	
125	146	267	138	63	102	131	130	117	289	128	94	123	171	97	106	speed	
0	50	50	25	75	25	25	0	75	75	50	50	25	50	50	25	comprehension	

Participant 13																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
																3	
*	*															4	
				*	*		*	*		*		*	*			5	
		*							*		*			*		6	
			*			*										7	
															*	8	
																9	
108	104	246	133	68	104	151	119	74	350	107	135	140	148	100	95	speed	
25	0	75	50	75	25	50	0	50	75	100	50	75	50	0	0	comprehension	

Participant 14																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
	*															3	
		*		*	*											4	
*							*		*	*						5	
						*		*			*		*	*		6	
			*									*			*	7	
																8	
																9	
119	104	304	145	74	90	127	126	113	333	111	144	130	159	109	116	speed	
0	25	50	50	25	25	25	50	100	25	50	0	25	25	100	0	comprehension	

Participant 15																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
	*															2	
																3	
				*												4	
		*			*		*				*					5	
*								*		*		*	*	*		6	
			*			*			*						*	7	
																8	
																9	
96	102	228	127	61	88	173	117	107	253	93	101	151	129	99	117	speed	
50	0	50	50	25	25	0	25	25	50	100	25	25	50	25	25	comprehension	

Participant 16																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
	*			*							*	*			*	3	
*							*			*			*	*		4	
					*	*		*								5	
		*							*							6	
			*													7	
																8	
																9	
102	124	100	81	174	80	99	102	70	100	84	100	128	113	76	126	speed	
25	75	75	25	100	100	75	100	75	75	25	100	25	50	75	50	comprehension	

Participant 17																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
	*															3	
*		*		*	*		*		*				*	*		4	
			*							*		*				5	
						*		*							*	6	
											*					7	
																8	
																9	
146	61	162	110	54	90	130	144	57	385	90	108	69	111	83	53	speed	
25	50	50	50	25	50	50	50	50	0	75	75	25	50	25	50	comprehension	

Participant 18																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
	*												*			2	
		*			*											3	
*								*			*					4	
			*	*		*	*					*				5	
										*				*		6	
									*						*	7	
																8	
																9	
159	122	242	124	77	213	167	180	67	660	97	172	207	144	126	141	speed	
75	25	50	50	50	50	50	50	50	50	50	50	0	50	50	25	comprehension	

Participant 19																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
	*															2	
				*												3	
*		*			*		*	*								4	
			*			*				*	*		*	*		5	
									*			*			*	6	
																7	
																8	
																9	
126	144	245	139	76	87	142	143	106	252	100	116	168	179	111	154	speed	
25	25	25	50	75	50	50	25	50	25	0	25	50	25	75	25	comprehension	

Participant 20																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
				*												3	
	*						*			*						4	
*		*	*		*	*			*			*	*			5	
								*							*	6	
											*			*		7	
																8	
																9	
136	123	248	162	76	93	149	152	85	229	115	121	134	142	100	114	speed	
0	50	25	25	25	50	75	0	50	25	50	0	50	25	25	25	comprehension	

Participant 21																	Name-Date	
Normal	6500			5000			4000			3000			2500				Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275		LUX	
																	1	Karolinska Sleepiness Scale
																	2	
	*																3	
		*															4	
*				*	*	*		*	*	*	*		*				5	
			*				*					*		*			6	
															*		7	
																	8	
																	9	
108	97	215	115	83	88	131	121	94	246	96	102	163	172	95	92		speed	
0	25	25	50	50	0	25	25	50	50	50	25	25	25	75	0		comprehension	

Participant 22																	Name-Date	
Normal	6500			5000			4000			3000			2500				Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275		LUX	
																	1	Karolinska Sleepiness Scale
																	2	
		*															3	
*			*		*	*											4	
	*			*			*		*		*			*			5	
								*				*	*		*		6	
										*							7	
																	8	
																	9	
107	126	245	148	63	94	133	141	101	277	98	105	165	136	94	108		speed	
25	50	50	0	25	50	50	0	75	25	25	50	50	25	50	50		comprehension	

Participant 23																	Name-Date	
Normal	6500			5000			4000			3000			2500				Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275		LUX	
																	1	Karolinska Sleepiness Scale
																	2	
				*													3	
	*												*				4	
*					*		*	*	*		*			*	*		5	
		*	*							*		*					6	
						*											7	
																	8	
																	9	
117	122	251	101	57	91	146	112	106	252	97	98	214	151	105	94		speed	
0	50	50	50	75	50	0	25	75	25	25	25	25	0	50	25		comprehension	

Participant 24																	Name-Date	
Normal	6500			5000			4000			3000			2500				Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275		LUX	
																	1	Karolinska Sleepiness Scale
		*												*			2	
				*						*			*				3	
*	*		*			*	*	*	*		*				*		4	
					*							*					5	
																	6	
																	7	
																	8	
																	9	
110	101	335	197	83	104	137	207	90	408	114	108	199	92	76	187		speed	
25	75	50	50	100	75	75	50	75	75	75	75	75	75	75	50		comprehension	

Participant 25																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
																3	
	*	*	*		*											4	
*				*		*	*		*	*	*	*	*	*	*	5	
								*								6	
																7	
																8	
																9	
159	200	315	291	85	112	192	155	60	232	74	121	165	96	61	96	speed	
50	75	25	0	25	100	75	75	100	100	50	25	100	25	25	100	comprehension	

Participant 26																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
		*			*								*			1	Karolinska Sleepiness Scale
							*	*		*		*				2	
	*		*	*							*			*	*	3	
						*			*							4	
*																5	
																6	
																7	
																8	
																9	
133	265	381	185	275	282	272	234	174	218	160	272	282	271	214	222	speed	
100	50	50	50	100	100	75	75	100	100	100	100	100	75	75	75	comprehension	

Participant 27																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
	*	*														3	
				*												4	
*					*		*	*		*	*			*		5	
			*						*			*	*		*	6	
						*										7	
																8	
																9	
99	130	290	145	80	94	157	136	111	266	91	114	161	178	100	140	speed	
25	25	50	0	25	50	75	0	50	50	75	25	25	50	50	25	comprehension	

Participant 28																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
																3	
				*					*							4	
*	*	*			*	*	*	*		*		*	*			5	
			*								*			*		6	
																7	
															*	8	
																9	
247	119	248	96	61	87	142	126	73	385	120	135	207	164	99	95	speed	
50	100	25	75	25	50	50	50	75	0	25	50	0	25	25	0	comprehension	

Participant 29																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
													*			2	
		*									*			*		3	
								*				*				4	
*	*			*	*		*								*	5	
			*						*	*						6	
						*										7	
																8	
																9	
177	108	213	96	172	138	112	146	76	224	95	177	152	142	196	115	speed	
75	75	75	75	50	100	75	25	75	50	75	75	100	100	50	75	comprehension	

Participant 30																Name-Date	
Normal	6500			5000			4000			3000			2500			Kelvin	
460	613	475	275	613	475	275	613	475	275	613	475	275	613	475	275	LUX	
																1	Karolinska Sleepiness Scale
																2	
	*															3	
*		*		*			*				*					4	
					*			*		*		*	*			5	
			*			*			*					*		6	
															*	7	
																8	
																9	
124	200	375	140	96	104	119	154	73	401	162	130	142	164	99	74	speed	
25	100	75	50	100	25	75	50	75	25	25	75	25	25	25	0	comprehension	

Appendix 9: An advertisement for research participants

Appendix 10: Reading materials

Name of the participant	Date	Base reading Time:

Name of research project: An Examination of the Affects of CCT on Cognition and Alertness in Students Reading Speed and Comprehension.

Lead researcher: Amal Alkhabra, University of Leeds, United Kingdom.

Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: General

Level: 8

Story: 1

Dust devils are whirlwinds or spinning columns of air. Such columns are called vortices. However, unlike tornadoes, dust devils are not associated with storm fronts or with clouds. They typically appear on dry, sunny summer days when there is little to no breeze.

Dust devils are caused by convection currents, heat transfer involving fluids, either liquids or gases. They occur in places, such as deserts, where temperature gradients form easily between different surfaces. Incident sunlight heats the ground, which radiates thermal energy into the air.

As the air warms, it rises and expands. It becomes less dense, and the air pressure falls. The difference in pressure between the two surfaces, ground and air, is small, but it is sufficient to set up a flow of air. The flow makes the rising air turn from an up-and-down path, and it begins spiraling.

In order to conserve its angular momentum, as the vortex rises its speed increases. All loose objects around the vortex, such as dirt and dust, are raised along with the air, making the dust devil visible.

1. Whirlwinds, or spinning columns of air, are called

A. tornadoes.

B. dust devils.

C. thunderclaps.

2. Dust devils are not associated with

A. storm fronts.

B. breezes.

C. weather patterns.

3. Dust devils are caused by

A. storm fronts.

B. convection currents.

C. thermal energy.

4. T As the air warms, it rises and

A. expands.

B. falls.

C. condenses.

Name of the participant	Date	6500K 275Lux Time:

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Lead researcher: Amal Alkhabra, University of Leeds, United Kingdom.

Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: General

Level: 7

Story: 1

Born a slave on a Missouri farm in 1864, George Washington Carver grew to become one of the most prominent Black scientists of his time. He devoted his life to research projects involved with Southern agriculture, especially with peanuts. In fact, the products he derived from both peanuts and soybeans revolutionized the Southern economy. It released farmers from an excessive dependence on cotton.

He was raised by his owners, Moses and Susan Carver, after his father was killed and his mother was kidnapped by slave raiders. He showed an interest in plants and a great desire to learn new things. The Carvers taught him to read and write, and, when he was 11, he attended a school for Black children.

Despite his poor beginnings, Carver managed to obtain a high school education. He was then admitted as the first Black student at Simpson College in Iowa. He followed up at Iowa Agricultural College; while working as a janitor, he received a degree in agricultural science in 1894. Two years later, he received a master's degree from the same school and became the first African-American to serve on its faculty. Within a short time, his fame spread, and Booker T. Washington offered him a post at what is now Tuskegee University.

Among his many accomplishments, Carver developed more than 300 products from peanuts. These included a milk substitute, face powder, printer's ink, and soap. He also created more than 75 products from pecans, more than 100 more products from sweet potatoes, and a type of synthetic marble made from wood shavings.

The world took note. Carver received many awards for his work. In 1916, he was named a fellow of the Royal Society of Arts of London. In 1923, the National Association for the Advancement of Colored People (the NAACP) awarded him a medal for distinguished service in agricultural chemistry. In 1939, he received the Theodore Roosevelt Medal for his contributions to science.

1. George Washington Carver was born on a Missouri farm in

A. 1864.

B. 1888.

C. 1894.

2. Carver devoted his life to research projects involved especially with

A. pecans.

B. sweet potatoes.

C. peanuts.

3. Carver was admitted as the first Black student of

A. Iowa Agricultural College.

B. Simpson College.

C. Tuskegee University.

4. The NAACP awarded him a medal for distinguished service in

A. agronomy.

B. scientific achievement.

C. agricultural chemistry.

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: General

Level: 7

Story: 2

On January 24, 1848, James Marshall discovered several small nuggets of gold at Sutter's Mill in California. The first printed notice of the discovery appeared on March 15 in the San Francisco Californian. Not long afterward, General John Bidwell discovered gold in the Feather River, and Major Pearson Reading found his own in the Trinity River. The combination of discoveries produced a rash of "gold fever." Almost half a million people began a stampede to the western United States in search of their own fortunes.

The gold continued to pour in. In 1849, quartz mining began at the Mariposa mine; gold deposits were found inside the veins of quartz. In 1850, gold-bearing quartz was also found at Gold Hill in Grass Valley. It led to the development of great underground mines and a gold-producing industry that continued for more than 100 years. By 1852, California's annual gold production reached an all-time high of 81 million dollars. The supply seemed inexhaustible. It appeared even more so when a 54-pound nugget was found in Butte County, and a 195-pound mass was found in Carson Hill.

When gold was discovered on the Fraser River in British Columbia, some miners began to head north. By 1855, the rich surface placers were largely exhausted in California, and, by 1864, California's gold rush had ended. Hydraulic mines became the chief sources of gold for the next 20 years.

1. Who discovered several small nuggets of gold at Sutter's Mill?

A. Pearson Reading

B. John Bidwell

C. James Marshall

2. California's annual gold production reached an all-time high of

A. 54 million dollars.

B. 68 million dollars.

C. 81 million dollars.

3. Gold was also discovered on the Fraser River in

A. Nevada.

B. British Columbia.

C. Oregon.

4. By what year had California's gold rush ended?

A. 1849

B. 1852

C. 1864

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: General

Level: 7

Story: 3

A man stood upon a railroad bridge in northern Alabama, looking down into the swift water twenty feet below. The man's hands were behind his back, the wrists bound with a cord. A rope around his neck was attached to a stout cross-timber above his head. The slack fell to the level of his knees. Some loose boards laid upon the ties supporting the rails of the railway supplied a footing for him and his killers - two private soldiers of the Federal army, directed by a sergeant who in civil life may have been a deputy sheriff. At a short remove upon the same temporary platform was an officer in the uniform of his rank, armed. He was a captain. A sentinel at each end of the bridge stood with his rifle in the position known as "support," that is to say, vertical in front of the left shoulder, the hammer resting on the forearm thrown straight across the chest -- a formal and unnatural position, enforcing an erect carriage of the body. It did not appear to be the duty of these two men to know what was occurring at the center of the bridge; they merely blockaded the two ends of the foot planking that traversed it.

Beyond one of the sentinels nobody was in sight; the railroad ran straight away into a forest for a hundred yards, then, curving, was lost to view. Doubtless there was an outpost farther along. The other bank of the stream was open ground -- a gentle slope topped with a stockade of vertical tree trunks, loopholed for rifles, with a single embrasure through which protruded the muzzle of a brass cannon commanding the bridge. Midway up the slope between the bridge and fort were the spectators -- a single company of infantry in line, at "parade rest," the butts of their rifles on the ground, the barrels inclining slightly backward against the right shoulder, the hands crossed upon the stock. A lieutenant stood at the right of the line, the point of his sword upon the ground, his left hand resting upon his right. Excepting the group of four at the center of the bridge, not a man moved. The company faced the bridge, staring stonily, motionless. The sentinels, facing the banks of the stream, might have been statues to adorn the bridge. The captain stood with folded arms, silent, observing the work of his subordinates, but making no sign. Death is a dignitary who when he comes announced is to be received with formal manifestations of respect, even by those most familiar with him. In the code of military etiquette, silence and fixity are forms of deference.

1. A man stood on a railroad bridge in northern

A. Alabama.

B. Alaska.

C. Altoona.

2. A sentinel at each end of the bridge stood with his rifle

A. in the position known as "unslung."

B. in the position known as "support."

C. in the position known as "unnatural."

3. The railroad ran straight way into a forest for a hundred

A. feet.

B. yards.

C. meters.

4. In the code of military etiquette, ______ are forms of deference.

A. respect and honor

B. formality and attention

C. silence and fixity

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: Fun Facts

Level: 7

Story: 1

Do you know the name Momofuku Ando? If you don't, you probably don't live in Japan, but you do know what made him famous - he invented the "instant" noodle, also called ramen noodles, that now you see in the soup aisle of every store.

Ando was born in Taiwan. Faced with the inevitable food shortages in post-World War II Japan, Ando thought a quality, convenient noodle product would help to feed the masses.

At 23, he entered Ritsumeikan University, and at the same time, he founded a small merchandising firm in Osaka. The company went belly up, and Ando went bankrupt. However, he didn't give up. In 1948, he founded what later would become Nissin Co., in Ikeda, Osaka. It was a small, family-run company that initially produced salt.

Ando was sure a product with such simple instructions (remove the ramen from its package and place it in a bowl. Add boiling water, cover, and wait three minutes) would be a hit, but the Japanese food industry was critical. It rejected the product as a novelty with no future.

But they were wrong. The packages sold beyond anyone's expectations, and over ten other companies rushed to put their versions on the market. By the end of 1958, it was a staple.

Today, each Japanese person eats about 45 portions of ramen (bags and cups combined), each year. It's catching on in the U.S., too. Consumers there eat about nine portions each year.

1. Instant noodles were invented by

A. Mashahiru Yakami.

B. Momofuku Ando.

C. Mono Andasu.

2. Ramen's creator thought a quality noodle product would

A. sell well.

B. establish him in the food industry.

C. help to feed the masses.

3. Nissin Co. originally produced

A. ramen.

B. salt.

C. cups.

4. **Today, each Japanese person eats about ______ of ramen per year.**

A. 9 portions

B. 45 portions

C. 60 portions

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Topic: Fun Facts

Level: 7

Story: 2

Our solar system is pretty well organized. There are the four, rocky, inner planets - Mercury, Venus, Earth, and Mars. There are the four outer gas giants - Jupiter, Saturn, Uranus, and Neptune. And then there's Pluto. It has enough matter to hold itself together like a ball. But its moon, Charon, is half its size. And it orbits the Sun at a different angle from the other planets.

Some years ago, the International Astronomical Union (IAU) voted to demote Pluto to what they called a "dwarf planet." Then things got complicated.

Ceres is an asteroid in the belt between Mars and Jupiter. But the description of the asteroid was similar to Pluto. They needed a way to tell the difference between rocky dwarf planets like Ceres and icy ones like Pluto.

They re-named Pluto as a "plutoid." This is a name for objects beyond Neptune's orbit. Shortly after this, they found another body, Eris, and its moons. It was similar to Pluto, and it was in the same region. It was called a plutoid, too. Then scientists thought again about Pluto. They thought maybe it was a planetessimal. The debate continues to this day over its status.

1. There are ______ rocky, inner planets.

A. three

B. four

C. five

2. The IAU voted to demote Pluto to a

A. planetoid.

B. pluton.

C. dwarf planet.

3. Pluto's largest moon is

A. Charon.

B. Eris.

C. Pluton.

4. A plutoid is an object

A. in the asteroid belt.

B. beyond Neptune's orbit.

C. in the Oort cloud.

0% Comprehension

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Lead researcher: Amal Alkhabra, University of Leeds, United Kingdom.

Please read the following text, and when you have finished the reading please answer the questions on the next page.

Topic: Fun Facts

Level: 7

Story: 3

Baseball is the "great American pastime," and one major aspect of the sport is the collecting and trading of special cards. Each of the cards has a Major League (or sometimes a Minor League) player on it, and it also has information about the player and his performance on the flip side.

Baseball had its beginnings in the mid-1800s, and by 1887, Goodwin & Company of New York City had produced the first nationally distributed cards. They inserted them into packs of cigarettes and tobacco, such as the "Old Judge" brand. The card had a small picture on it, and the card fit in the wrapper with the tobacco, stiffening it. With less damage to the packs and a "freebie," as well, sales increased enormously.

In order to compete in the trading card market, other tobacco companies began placing cards in their packs. Topps Company began to produce baseball cards in 1951, and since they wanted to market them to children, they put the cards in packs of gum. Some cards were more "valuable" than others, and kids traded one for another to improve their collections.

All of the tobacco cards were much smaller than the cards of today, and they are extremely rare and valuable. One of the most famous is the 1909 T-206 Honus Wagner card. It has sold at auctions for over $1 million.

1. Baseball had its beginnings in

A. the mid-1800's.

B. 1887.

C. 1903.

2. Nationally distributed cards were produced by

A. Major League Baseball.

B. Old Judge.

C. Goodwin & Company.

3. The company inserted the cards into

A. packages of gum.

B. the tobacco wrapper.

C. the retail market.

4. The 1909 T-206 card is the most

A. popular.

B. valuable.

C. interesting.

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: American History

Level: 7

Story: 1

President Franklin D. Roosevelt died in 1945, at the end of World War II. After his death, Vice-President Harry S Truman became the thirty-third President of the United States. Previously he had served as the Democratic Senator from Missouri.

At first, Truman did not feel he was ready to govern the United States. Roosevelt had not spoken to him about post-war issues, and he had little prior experience in international affairs. "I'm not big enough for this job," he told a former colleague.

But Truman responded quickly to new challenges. He was willing to make fast decisions about the problems he faced. A now-famous sign on his White House desk read, "The Buck Stops Here." This reflected his willingness to take responsibility for his actions. His judgments about how to respond to the Soviet Union had an important impact on the early Cold War.

1. President Roosevelt died in

A. 1495.

B. 1954.

C. 1945.

2. Harry S Truman had previously served as a

A. Representative.

B. Senator.

C. Governor.

3. A famous sign on Truman's desk read,

A. "This One is for You."

B. "Do Not Enter."

C. "The Buck Stops Here."

4. President Truman was the

A. thirty-first President.

B. thirty-second President.

C. thirty-third President.

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: American History

Level: 7

Story: 2

Professional football was first played around 1895. In 1920, the American Professional Football Association was formed. The APFA handed out franchises right and left, and it ended up with 23 teams. One year later, it changed again, and, in 1922, it was renamed the National Football League.

The NFL was limited to only ten teams, which then grew to 16. In 1970, the NFL teams merged with 10 American Football League (AFL) teams to form one league with two divisions. The result was the first modern professional football association.

In the 1980s, further expansion was proposed, and by the 1993-1994 NFL season, approval was given for a thirty-team league. The next step towards growth of the league was to separate the NFL into eight different divisions, each with four teams.

1. Football was first played around

A. 1895.

B. 1910.

C. 1920.

2. In 1920, what football association was formed?

A. AFL

B. NFL

C. APFA

3. The NFL consisted of ______ NFL teams.

A. six

B. sixteen

C. sixty

4. The APFA was renamed the

A. American Football League.

B. Canadian Football League.

C. National Football League.

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: Earth & Space Science

Level: 7

Story: 1

A tornado is one of the most destructive types of storms. From the Spanish word for "to turn," a tornado is a violently spinning, funnel-shaped cloud that reaches down from a storm cloud to touch the Earth's surface. It is likely to occur when thunderstorms are most common - in spring and early summer, when the ground is warm. It is often joined by severe thunder, lightning, and a high volume of rain. The funnel is visible because it sucks up dust from the ground.

Tornadoes are usually very brief. They may touch down for 15 minutes or less and be only a few hundred meters across. Wind speeds, though, may reach 480 kilometers per hour.

Tornadoes occur more frequently in the United States than in any other country - there are about 800 each year. Most of these are in the Great Plains region of the country. The Plains run from north-central Texas across central Oklahoma, Kansas, and Nebraska. This region is often referred to as "tornado alley."

1. When is a tornado most likely to occur?

A. Spring and fall

B. Spring and summer

C. Fall and summer

2. Wind speeds in a tornado may reach

A. 430 kilometers per hour.

B. 450 kilometers per hour.

C. 480 kilometers per hour.

3. How many tornadoes occur in the United States each year?

A. 600

B. 800

C. 1000

4. **The word "tornado" comes from the Spanish for**

A. "to spin."

B. "to whirl."

C. "to turn."

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: Earth & Space Science

Level: 7

Story: 2

A rock that contains a metal or other useful mineral is known as an ore. Most metals do not occur in a pure form. They are combined with other elements in the ore. Ores must be processed before the metals can be used. The removal process is called smelting.

To remove the metal, the ore is mixed with other materials. The entire mixture is heated to a very high temperature, which melts the metal. This also causes it to separate from the oxygen atoms to which it is attached. The molten metal is then poured off into a separate chamber.

After smelting, the metal is processed further to remove any impurities. In the case of iron, the result is steel. It is harder and stronger than pure iron. The metal may also be combined with other elements to give it special properties, such as strength or rust resistance. The combination is called an alloy.

1. A rock that contains a metal or useful mineral is known as a(n)

A. ore.

B. mine.

C. alloy.

2. Heating the mixture to a high temperature causes the metal to

A. melt.

B. separate.

C. depurify.

3. The removal process is called

A. extraction.

B. smelting.

C. separation.

4. The result of removing the impurities from iron is

A. alloy.

B. steel.

C. resistance.

0% Comprehension

Name of the participant	Date	6500K 613Lux Time:

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: Earth & Space Science

Level: 7

Story: 3

The Earth is more than just a ball of rock - part is solid, part is liquid, and part is gas.

The Earth is divided into four major layers. The first layer is the interior, and it is made up of the liquid iron inner core and the solid iron and nickel outer core.

The second is the lithosphere, which is composed of the mantle just below the surface and the crust of rock and soil.

The third is the hydrosphere, which is formed by all of all the bodies of water, including the water below the ground and that found in the atmosphere.

The fourth is the atmosphere, which is made up of the blanket of air, dust, water, and ice particles that covers the lithosphere and the hydrosphere.

Earth science deals with all four regions, plus the space beyond.

1. Into how many layers is the Earth divided?

A. Three

B. Four

C. Five

2. The inner core is made up of

A. liquid iron.

B. solid iron and nickel.

C. water.

3. The hydrosphere is made up of

A. the inner and outer cores.

B. a blanket of air, dust, water, and ice particles.

C. all bodies of water.

4. The crust is composed of

A. liquid iron.

B. rock and soil.

C. water particles.

Name of the participant	**Date**	**5000K 613Lux** **Time:**

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: American History

Level: 7

Story: 3

In 1929, the United States economy was in trouble. When it collapsed that year, it affected not only our country, but also the entire world. Those ten long years were called the Great Depression.

Many factors played a role in bringing about the Depression. However, the main causes were the unequal division of wealth during the 1920s, along with the risky stock market dealings during that time. Eventually, the stock market crashed, and the economy fell apart. Many people lost their jobs during this time, and it became hard to find new work.

1. In what year did the Great Depression start?

A. 1919

B. 1929

C. 1939

2. What factors contributed to the Depression?

A. Politics and the stock market

B. Unequal wealth and the stock market

C. Jobs and the stock market

3. It became hard to find

A. housing.

B. money.

C. new work.

4. How long did the Depression last?

A. 10 years

B. 20 years

C. 30 years

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: Fun Facts

Level: 8

Story: 1

The Earth orbits the Sun, and each orbit equals one calendar year. The Earth also revolves around its own axis, and each revolution equals one day. To remove the discrepancies between atomic and astronomical time, we change the calendar, as needed.

Once every four years, we add one full day to the calendar. Since February is the shortest month, with only 28 days, we add the day there - February 29. Each year, we also change the clocks either forward or backward by a single second. This happens on June 30 and December 31, and it is done when the times don't align properly.

The determination as to whether such an adjustment is necessary falls to the International Earth Rotation Service of the International Bureau of Weights and Measures in Paris. The announcement to insert a leap second is given whenever the difference between the two-time clocks approaches one-half second; after UTC (Universal Time Code) 23:59:59, a positive leap second is inserted at 23:59:60, that is, before the clock indicates 00:00:00 of the next day. Negative leap seconds are also possible, should the Earth's rotation become slightly faster; in that case, 23:59:58 would be followed by 00:00:00.

1. Each orbit of the Sun equals one calendar

A. day.

B. month.

C. year.

2. Each year, we always

A. add February 29.

B. adjust the calendar.

C. change the clocks by one second.

3. We change the calendar to remove discrepancies between

A. Earth's orbit around the Sun.

B. atomic and astronomical time.

C. how long it takes the Earth to rotate.

4. Negative leap seconds are possible if the Earth's rotation becomes

A. slower.

B. faster.

C. unstable.

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Please read the following text, and when you have finished the reading, please answer the questions on the next page.

Topic: Fun Facts

Level: 8

Story: 2

Fossils can tell us a great deal about the past. Studying fossils, researchers have found the oldest known fossil animal. It is called an archeopteryx. The researchers believe it is the "missing link" between dinosaurs and birds. It contains features of each.

On the one hand, the fossil shows clear impressions of feathers. The animal "frozen" in time has an expanded braincase. It also has large eye sockets and a pronounced beak, just like those of modern birds. In addition, the animal's hind legs have three claws at the ends. Also, it has well-developed wings. The structure and arrangement of its feathers indicate it could fly.

On the other hand, it appears to have well developed teeth, like a theropod (meat-eating dinosaur). It also has a long, well-formed tail. These are traits that are like those of small dinosaurs. Scientists can only guess about its status until more such creatures are found to support their theory.

1. Researchers believe the archaeopteryx is the

A. oldest known fossil.

B. missing link.

C. simplest form of bird.

2. The animal's hind legs have ______ claws.

A. three

B. four

C. five

3. It appears to have well-developed

A. teeth.

B. muscles.

C. talons.

4. **The fossil has an expanded**

A. wing structure.

B. skeletal structure.

C. braincase.

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Topic: Fun Facts

Level: 8

Story: 3

Mother's Day in the United States is celebrated on the second Sunday in May. Other countries, such as the United Kingdom, Denmark, Finland, Italy, Turkey, Australia, Mexico, Canada, China, Japan, and Belgium all have similar celebrations.

England has a "Mothering Sunday," which is similar but not identical to Mother's Day elsewhere in the world. It is also called "Mid-Lent Sunday," and it is observed on the fourth Sunday during Lent. Even England's tradition is giving way to the modern celebration. Now it is held the second Sunday in May there, too.

Anna Jarvis, born in Grafton, West Virginia in 1864, was the person who started the holiday. She believed that mothers should be honored for their work. She wrote letters to politicians, newspaper editors, and church leaders. She organized a committee called Mother's Day International Association to promote the new holiday. She wanted it to be close to the Memorial Day holiday. That's so people would recognize mothers for the sacrifices they made in the same way that service people made sacrifices for their country.

The first official Mother's Day was in May 1907. President Woodrow Wilson gave the day national recognition in 1914. In a strange twist of fate, Jarvis spent the last years of her life trying to abolish the holiday. She believed it was a business venture for many companies. She believed it no longer served its true purpose.

1. Mother's Day is celebrated on the second Sunday of

A. March.

B. May.

C. June.

2. The person who started the holiday was

A. Virginia Jefferson.

B. Jennifer Anholm.

C. Anna Jarvis.

3. In England, it's also called

A. "Mother's Sunday."

B. "Mothering Day."

C. "Mid-Lent Sunday."

4. The creator felt the holiday became a[n]

A. memorial.

B. business venture.

C. important event.