Kuwait University

The Effects of Correlated Color Temperature and Illuminance on Attention and Mood of Students in a Classroom

Submitted by:

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A Thesis Proposal Submitted to the College of Graduate Studies in Partial Fulfillment of the Requirements for the M. Sc Degree in:

Architecture

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Kuwait

January/ 2020

Kuwait University

College of Graduate Studies

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Abstract

This thesis aims to investigate the effects of correlated color temperature (CCT) lighting and illuminance on university students' attention and mood through six conditions. It is known that higher CCT lighting influences worker productivity and visual comfort. Therefore, it is essential to examine if high CCT lighting compared to the existing and low CCT lighting would influence student attention and mood positively. This thesis also examines the debate on the Kruithof curve in terms of pleasantness through different ranges of illuminance. Three different CCT (2700 K, 4600 K, and 6500 K) fluorescent lighting types with two ranges of illuminance (300 lx and 600 lx) were tested individually. The eighteen participants (87.5% female) were tested with three paper-based tests: the d2 attention test and two tests of Positive and Negative Affect Schedule (PANAS). The results indicate that higher illuminance decreases university student errors and increases participant concentration.

Keywords: Correlated Color Temperature (CCT), Vertical Illuminance, D2 Attention, PANAS, Lighting Quality, Color of Light.

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Attention is generally the act of fixing the mind on something.

CCT stands for correlated color temperature. It is defined as the light temperature measured in Kelvin and a metric for the color appearance of the measured light temperature.

Cool white stands for 4600 K "color temperature of the light bulb".

CP stands for concentration performance. It is the number of the correct items minus the error of commission.

Daylight stands for 6500 K "color temperature of the light bulb".

E% stands for percentage of error. It is the percentage of the total errors within the total items processed.

EC stands for error of commission. It occurs when the participant crosses out the irrelevant letters.

EO stands for error of omission. It occurred when the participant did not cross out the relevant item (d with two dashes).

Fluorescent Lamp is a light that produces light through fluorescence.

FR stands for fluctuation rate.

IES stands for illumination engineering society.

Lighting quality is defined as a term used to describe all of the factors in a lighting installation not directly connected with the quantity of illumination.

Luminaire is a complete electric light unit.

Luminance is a measure of brightness. The luminous intensity (photometric brightness) of a light source or reflecting surface includes factors of reflection, transmission, and emission.

Lx stands for illuminance. It is defined as the amount of light that falls onto a specific surface area.

Melatonin is a hormone that regulates the sleep–wake cycle.

Mood refers to feelings that tend to be less intense than emotions and that often lack a contextual stimulus.

PANAS stands for Positive and Negative Affect Schedule.

Plankain locus is the plot or the graphical outlook that a blackbody having the ability to emit a given spectrum of light will take if its temperature is gradually raised within a stated chromaticity.

SPSS stands for Statistical Package of Social Sciences.

TN is the total number of items processed.

TN-E stands for number of items processed minus the total errors.

Warm white stands for 2700 K “color temperature of the light bulb”.

Acknowledgments

I would like to express my thanks to my parents and wife for their unlimited support to complete my study.

I would also like to extend my thanks to the Maintenance Department at Kuwait University for their support in installing the new lighting luminaire in the classroom.

CHAPTER 1

INTRODUCTION

1.1 Lighting Quality

Lighting is a major aspect of designing all types of buildings. According to Bellia at el (2017), individuals predominantly spend their time inside buildings, which motivates designers to achieve a pleasant environment and avoid harmful effects on an individual's "health and performance." The importance of lighting is a scientific subject that researchers tackle to improve occupants' pleasantness, comfort, and health. Loe and Mclntosh (2014) presented a variety of leading researchers and topics over the last decade in the lighting sector. Thus, the importance of lighting is an old scientific subject that researchers aim to improve and achieve the occupants' maximum level of pleasantness.

Lighting quality promotes and improves occupant performance, behavior, and visual comfort (Kralikova et al., 2016). Lighting quality is defined as a "term used to describe all of the factors in a lighting installation not directly connected with the quantity of illumination" (Stein et al. as cited in Veitch, 2001). According to Boyce (2014), many approaches have defined lighting quality (Loe and Rowlands, 1996; Bear and Bell, 1992; Veitch and Newsham, 1998). However, the definition that seems most relevant is that "lighting quality is given by the extent to which the installation meets the objectives and the constraints set by the client and the designer" (Boyce, 2014).

Lighting quality is affected by several factors and variables that should be taken into consideration. It emerges from three integrated aspects: individual well-being, economics, and architecture, as shown in Figure 1.1 (Veitch, 2001). Veitch (2001) referred to the quality of lighting as a balance among these three aspects.

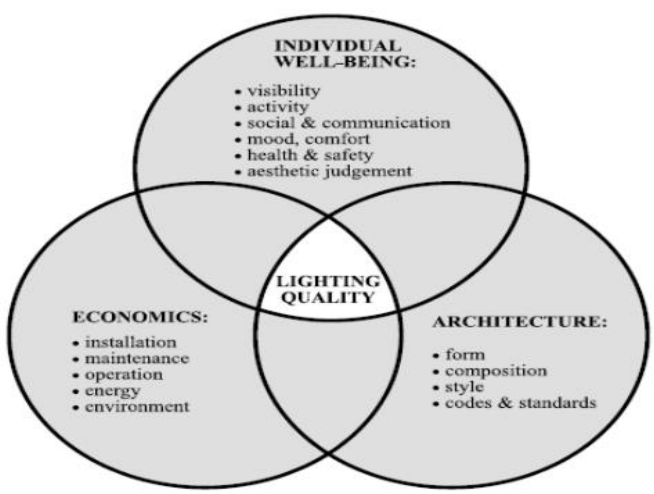


Figure 1.1: The three integration aspects of lighting quality (source: Veitch, 2001)

Thus, the previous definition of Boyce integrated these three factors into defining the "lighting quality." This paper consolidates these aspects to determine student attention and mood under several lighting set-ups.

There are several variables that affect the lighting quality: age, gender, preference, knowledge, color, illuminance, and attitude (Veitch and Newsham, 1998; Knez, 1995; Knez and Kers, 2000; Boyce, 2014). Knez and Kers (2000) investigated the effects of indoor lighting, gender, and age on mood and performance through eighty participants, who were randomly assigned in two different lighting set-ups. The results of the experiment indicated that lighting quality is affected by those variables. Veitch and Newsham (1998) concluded that the quantity of light, luminance distribution, and illuminance uniformity are vital contributors to lighting quality. Hence, this paper focuses on illuminance (lx) and correlated color temperature (CCT). Illuminance is defined as the amount of light that falls onto a specific surface area. Correlated color temperature is defined as the light temperature measured in Kelvin and a metric for the color appearance of the measured light temperature (Boyce, 2014). Both illuminance and CCT could play a significant role in occupants' performance and behavior. Viola et al. (2008) concluded that exposure to blue-enriched white light improves alertness and subjective performance. This conclusion is supported by Zhu et al. (2017), who stated that participants felt less sleepy in bright light conditions: (6500 K, 1200 lx) compared to (3000 K, 200 lx).

Furthermore, the Illumination Engineering Society (IES) publishes the Lighting Handbook, which provides insight into the important references in the lighting community. Lighting for education is an essential aspect of the Lighting Handbook, which specifies the minimum standards for the illuminance (lx) for various conditions (DiLaura, Houser, & Mistrick, 2011). By contrast, CCT has no specific standard or code, especially in the learning sector.

It is important to study the relationship between illuminance and CCT on student mood and attention. Kruithof created a graph that dealt with the combination of illuminance and CCT for indoor lighting (Fotios, 2017). The graph provides the "pleasant range" of different CCT and illuminance. However, there were several attempts to validate the boundaries of the Kruithof graph (Boyce and Cuttle, 1990; Davis and Ginthner, 1990). Thus, the results of this research paper will be compared with the Kruithof graph and the revised Kruithof graph.

1.2 Learning Sector in Kuwait

The learning sector is one of the most valuable sectors in any society. The total amount of all types of schools in Kuwait is around 1450 with 24,500 classes (AlHamadi, 2016). Furthermore, most of these classrooms have recessed fluorescent luminaire (60x60), in which the luminaire is placed in an identical distance and half the distance to the wall. The typical illuminance is around 300 lx, as stated in the IES Lighting Handbook. However, the

CCT of these classrooms varies from the daylighting to the warm conditions because there is no specific standard for CCT in the learning sector.

This research focuses on undergraduate students in the College of Architecture at Kuwait University. These undergraduate students have a better understanding of indoor lighting, and according to Veitch and New (1998), knowledge is a vital aspect that affects the lighting quality. Thus, the research will contribute and question whether CCT should be specified in codes for all types of learning sectors.

1.3 The Aim of the Study

The goal of this research is to investigate the effects of the illuminance and CCT relationship on student attention and mood. The result of this research will be compared between the Kruithof graph and the revised Kruithof graph. There is a gap in the literature review on the effects of the illuminance and CCT on student performance, mood, and attention. Thus, this study fulfills the gap, especially in the education sector.

Therefore, the research has seven hypotheses to be tested through an experiment.

1- CP (concentration performance) values are higher in 6500 K, 300 lx condition compared to 4600 K, 300 lx, and 2700 K, 300 lx.

2- E% of the d2 test of attention decreases at 6500 K compared to 4600 K and 2700 K all at 300 lx.

3- CP (concentration performance) increases at the highest CCT and illuminance condition (6500 K, 600 lx) compared to 4600 K and 2700 K all at 600 lx.

4- E% of the d2 test of attention decreases at 6500 K compared to 4600 K and 2700 K at (600 lx).

5- CP (concentration performance) values are higher in 6500 K, 600 lx than all other conditions.

6- E% of the d2 test of attention is lower at 6500 K, 600 lx than all other conditions.

7- Student's PA (positive affect) in the mood test increases at the highest CCT and illuminance (6500 K, 600 lx).

1.4 Study Approach

The research will be structured as six chapters. They include a brief summary of each chapter examined in the study.

1.4.1 Chapter 1: Introduction of Lighting Quality

This chapter gives a brief introduction of lighting quality and the aspects that affect lighting quality. It also includes the aim of the study and the hypotheses.

1.4.2 Chapter 2: Literature and Research

This chapter illustrates the research that deals with the effect of lighting on human vision, mood, and attention. The first phase introduces indoor lighting in the educational sector. Then it defines and illustrates the correlated color temperature and illuminance terminology and investigates the effect of lighting on the human eye and vision. Moreover, it defines and investigates the Kruithof graph and the revised Kruithof graph.

The second phase defines and illustrates the effect of lighting on mood. In addition, it explains the first qualitative data (PANAS test) that is used in this research.

The last phase defines and illustrates the effect of lighting on attention. Furthermore, it demonstrates the second qualitative data (d2 test of attention) used in this research.

1.4.3 Chapter 3: Experiment Methodology

This chapter states the questions and the hypotheses of this research. It also illustrates the methodology of the experimental approach of this research.

1.4.4 Chapter 4: Experiment Statistical Analysis

This chapter uses SPSS statistical package to analyze the qualitative data of the PANAS and d2 test of attention tests. The analysis is divided into three phases in order to test and verify the hypotheses of this research.

1.4.5 Chapter 5: Discussion

This chapter is divided into six sub-headings in order to discuss the results of the SPSS analysis and to verify the hypotheses of this research. Furthermore, the results are compared with the initial Kurithof curve and the revised Kurithof curve.

1.4.7: Chapter 6: Conclusion

This chapter provides a conclusion to the research. It also identifies the limitations of this study and proposes recommendations for further research papers.

1.5 Methodology

This research investigates electric lighting only in a classroom which is not affected by daylight. Additionally, it examines leading sources of indoor lighting on participants' attention and mood. The literature review analyzes the definitions and relevant studies, and it also investigates the effects of CCT and illuminance on student mood and attention. The experiment of this paper is undertaken six times with six different conditions (the same subjects are assigned to the six conditions) as shown below.

1. Condition #1 (6500 K, 300 lx): The subjects will do the PANAS test before the lecture. After several minutes of the lecture, subjects will be tested using the d2 test of attention. In the middle of the lecture, subjects will take the PANAS test again.

2. Condition #2 (6500 K, 600 lx): The subjects will take 10 minutes to continue their lecture before starting the PANAS questionnaire of the second condition. In these 10 minutes, the new luminaires will be switched on to achieve the new condition. Then, the subjects will take the PANAS test. After several minutes, subjects will perform the d2 test of attention test. Finally, subjects will retake the PANAS test.
3. Condition #3 (4600 K, 300 lx): The subjects will follow the same procedure as condition #1.
4. Condition #4 (4600 K, 600 lx): The subjects will follow the same procedure as condition #2.
5. Condition #5 (2700 K, 300 lx): The subjects will follow the same procedure as condition #1.
6. Condition #6 (2700 K, 600 lx): The subjects will follow the same procedure as condition #2.

CHAPTER 2

Review of Literature and Research

2.1 Indoor Lighting on Education Sector Background

Lighting quality influences the outcomes of the learning process. Indoor lighting, therefore, directly impacts the performance of learners. The impact arises from the role that light plays in the internalization of knowledge. According to Samani and Samani (2012), knowledge acquisition is influenced by one's immediate environment. In addition, Samani and Samani (2012) make inferences to the work of Nonaka and Konno (1998), who highlighted that the internalization of knowledge is through physical and mental stimulants that act on human cognition. On physical stimulants, light is mentioned as one of the most important elements. Samani and Samani (2012) assert that light influences how one acquires knowledge. Undeniably, learning is best actualized in an environment where the learner is comfortable. Taylor and Enggass (2009) contributed the concept that lighting should simulate natural settings to conserve energy and comfort. In this regard, a combination of factors contributes to comfort. The primary aspect among these is the internal design of the learning environment (Sleegers et al., 2012). The internal design, in this case, has to incorporate an array of factors such as color, cleanliness, noise minimization, and lighting.

In a learning environment, quality lighting plays different roles. Proper illumination ensures that learners can sight different surfaces (Taylor & Enggass, 2009). In a typical learning environment, media presentations are often incorporated into the curricula. It should be noted that is only with good lighting that learners can see, read, and visualize these presentations. There are other surfaces whose visibility is affected by the quality of the illumination within the learning environment. These include books, computer screens, or even blackboards.

In addition, light also influences the psychological wellbeing of the learners. These findings are supported by a Dutch study (Sleegers et al., 2012). According to Sleegers et al. (2012), lighting improves the concentration of learners in many positive ways. Illumination, in combination with the right correlated color temperature (CCT), influences participants vision. This combination comes from the interaction of the physical stimulus and the body, which then influences the psychological state of the learner. The psychological processes experienced by the learners arise from their perception of their immediate environment, which is directly influenced by illumination, or lighting. Therefore, a productive learning environment is often characterized by ideal learning. There are arguments that lighting also influences the moods of learners (Sleegers et al., 2013; Smolders et al., 2017; Kuller et al., 2016; Baron et al., 1992). When stimulated effectively through lighting, the implication is that learners tend to work towards improving their productivity and performance.

According to Samani and Samani (2012), lighting plays an essential role in knowledge dissemination, which implies that the interior design of learning spaces has to take that realization into consideration. However, it is also important to consider the economic and architectural implications and costs of learning spaces. More importantly, the architectural design and economic implication of a learning space should be aimed at improving the lighting for the sake of stimulation of knowledge dissemination and acquisition (Sleegers et al., 2012). This realization will form the basis of the following discourse: the importance of lighting on student performance and mood in the educational sector. Thus, the educational sector should improve and use appropriate lighting to help learners in knowledge acquisition.

2.2 Illuminance (Lx)

According to DiLaura et al. (2011), lighting can be segregated into two attributes. These are highlighted as the quantity of light as well as the quality of light. The quantity of light, according to DiLaura et al. (2011), is referred to as illuminance. This is the segregation upon which lighting recommendations are based. On the other hand, quality of light deals with other aspects such as color, visual, comfort, distribution, spatial ordering as well as psychological setting (DiLaura et al., 2011). Illuminance is defined in simple terms as the amount of light which gets to a given surface or area. In technical terms, it is defined as the quantification of the luminous flux which reaches a given surface. The surface is measured per unit area. According to DiLaura et al. (2011), the body which is responsible for coming up with recommendations on lighting designs is the Illuminating Engineering Society (IES). The IES assigns lighting codes as the recommendations for various lighting designs. It should be noted that illuminance recommendations are not only based on vision. According to DiLaura et al. (2011), the basis of recommendations, including for the education sector, is experience as well as proven good practice. In the education sector, the minimum lx per code is 300.

2.3 Correlated Color Temperature (CCT)

Mazin, Delon, and Gousseau (2012) stated that the correlated color temperature (CCT) is the color specification which is assigned to the light emitted from a given flame. The color is often compared to the color of an identified source which has to be heated to a given temperature. This is usually measured through determining the chromaticity of the given light source to what is known as a blackbody locus. The CCT gives the estimated wavelength of light. Therefore, as noted by Loe and McIntosh (2009), it can also be used as a measure of the purity or hue of a given source of light.

The Planckian locus is referred to as the plot or the graphical outlook that a blackbody having the ability to emit a given spectrum of light will take if its temperature is gradually raised within a stated chromaticity (Ju et al., 2012). The graphical plot of the behavior of the blackbody is known as the Plankain locus. The CIE 1931 (x, y) chromaticity diagram (Figure 2.1), therefore, is just a plot of the CIE 1931 observations, which were normalized and standardized (Schnada, 2007). The plot was the creation of the International Commission on Illumination of 1931. The plot comes about from the results of two separate experiments, which were conducted on 10 and 7 observers by William David and John Guild respectively. The observations were combined and then plotted on a graph. It is the standardized graph, which was a project of the CIE, that led to the renaming of the plot as CIE XYZ color space.

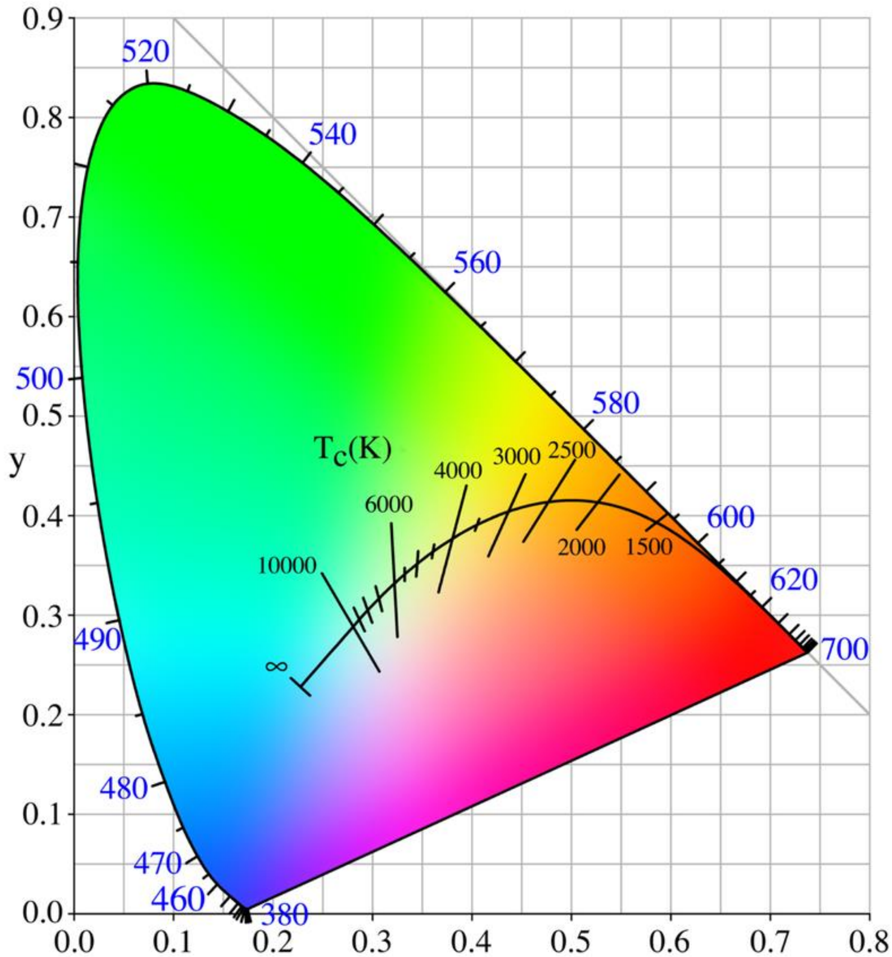


Figure 2.1: X, Y chromaticity diagram (Source: Dilaura, 2011)

The CCT range can be used to classify light: the lower the CCT, the lower the temperature. According to Schanda (2007), warm light on the CIE 1931 (x, y) would have a lower value of CCT (2000 K – 3000 K). On the other hand, the CCT values for daylight are higher (5000 K – 6500 K), as shown in Figure 2.2. Thus, lighting with high CCT has higher temperature whereas those with lower CCT have lower temperatures. Colors with high CCT include blue and white, but yellow and red have lower CCT. The phenomenon arises from the perception of "cool" by human eyes. Blue and white are perceived by the eye to be cool while yellow and red lighting is perceived to be warm (Ju et al., 2012). This can also be explained by the spectral characteristics of sources of light. To emit more light, the temperature of an incandescent source is increased (Ju et al., 2012). Thus, blue needs more energy (higher temperature) than yellow lighting.

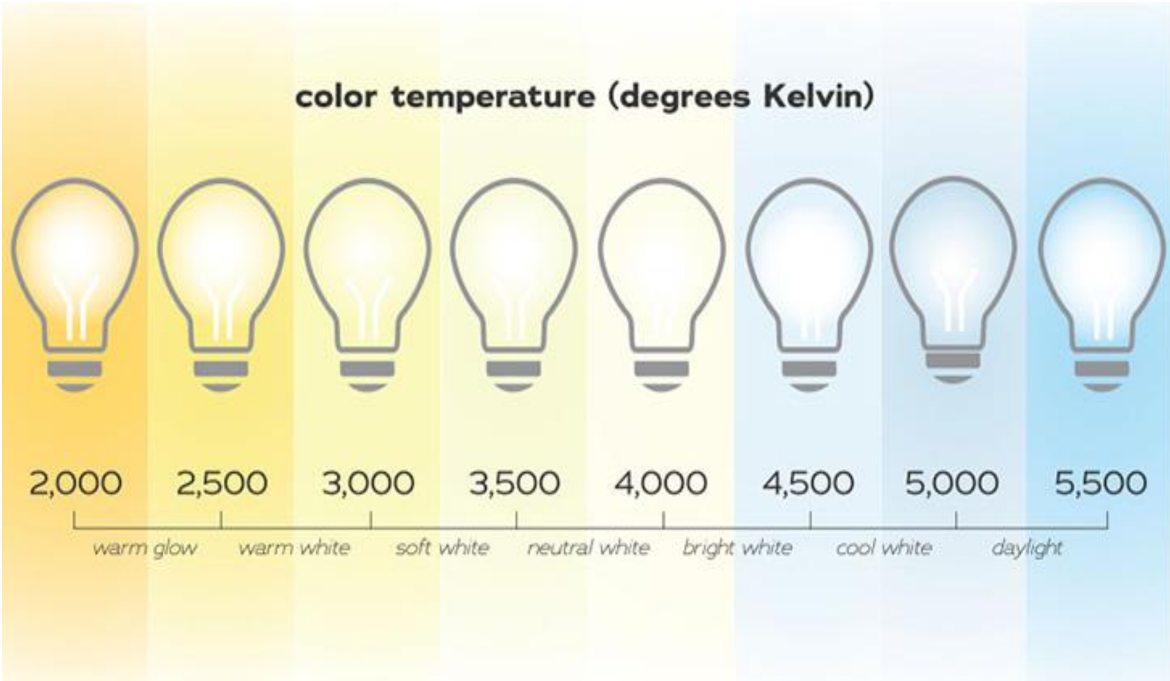


Figure 2.2: The color temperature of the light bulb (source: Rethlake, 2018)

2.4 The effect of lighting on the human eye

The human eye is the organ through which people respond to light as a stimulus; it provides humans the ability to see. DelMonte and Kim (2011) assert that the eye's outermost layer is white in color due to the sclera, which comes right after the transparent retina. The vascular mid-section of the eye contains the iris, uvea, and choroids. The last component of the human eye is the retina (Figure 2.3). This is arguably the innermost part of the eye, where vision is usually facilitated. The innermost part of the eye has rods together with cons (Figure 2.4). Rods are responsible for vision in low light, or what is termed as scotopic vision. On the other hand, the cons are responsible for vision in high lights. The cons are responsible for photopic vision (DelMonte & Kim, 2011). The spatial acuity of rods is high; thus, they are responsible for vision. Different kinds of cons depend on their response to light at different wavelengths. There are cons for short, middle, and long wavelengths.

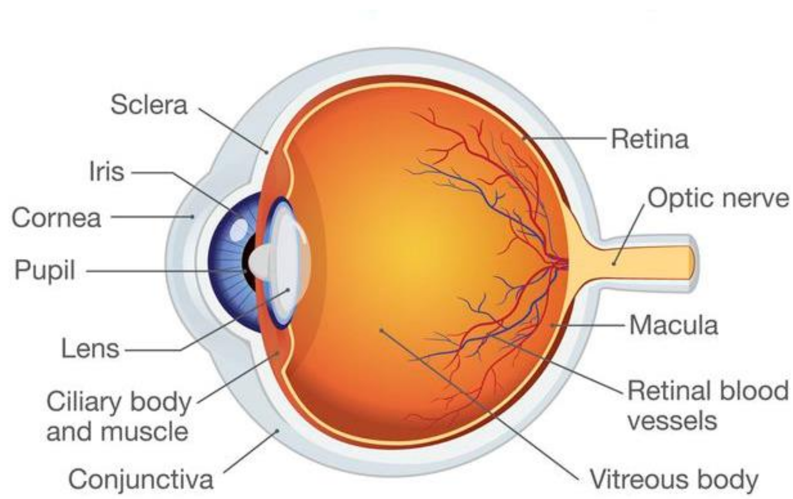


Figure 2.3: The structure and form of the human eye (Source: Helmenstine, 2019)

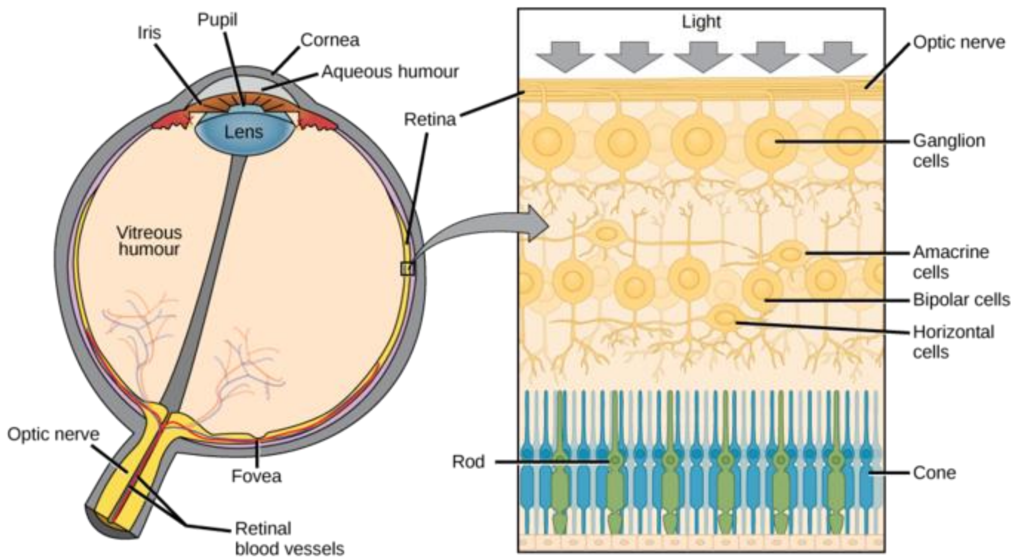


Figure 2.4: A cross-section of the retina (Source: courses.lumenlearning.com)

The circadian system refers to the biological cycle that controls "wake-up time" in humans. Basically, it influences when people sleep or wake up. The circadian system works through the secretion of a hormone which is known as melatonin (Figure 2.5). According to Chellappa et al. (2011), melatonin works by inducing sleep thus enabling one to fall asleep. Lighting, in contrast, inhibits the secretion of melatonin from the pineal gland. When that happens, the implication is that the circadian system interferes with this secretion, so a person is unable to sleep (Chellappa et al., 2011). The effect, however, is only initiated by light at certain wavelengths. Lighting at a lower wavelength has been proven to suppress melatonin secretion at higher sensitivity (Claustrat & Leston, 2015).

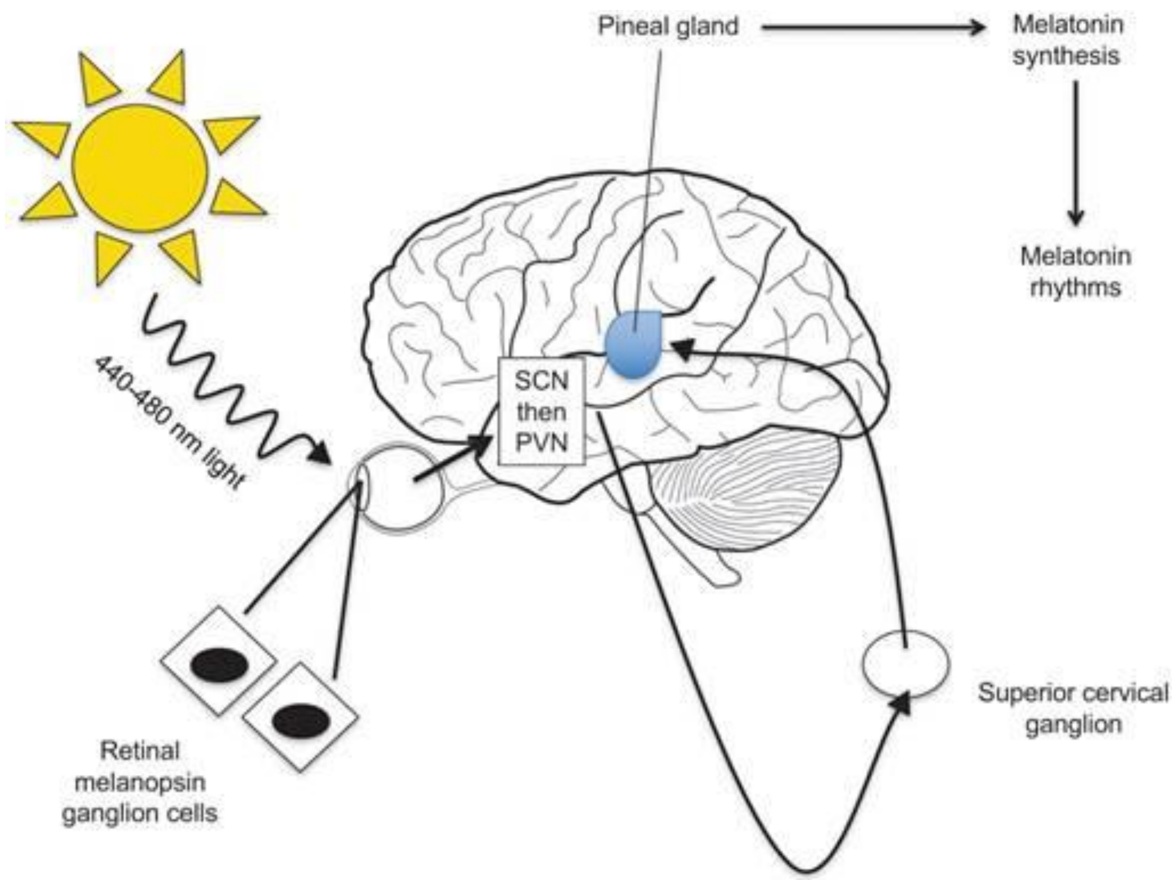


Figure 2.5: The location and role of melatonin (Source: Liu et al., 2018)

The physiology of the eye adapts it to its functions. For instance, the eye is held by the orbital socket, which makes sure that it is in place. The eye is also aptly cushioned by layers of fat, which offer it insulation from physical shocks (DelMonte & Kim, 2011). Above all, the eye has muscles to ensure that it can move in any direction with the intention of capturing the right image.

According to DelMonte and Kim (2011), the retina helps in the formation of the images that people see in real life. The eye has many curved surfaces, which focus the light that enters it onto one point, known as the focal point. The curved nature of the eye creates a biconvex lens. At the focal point, the light is then beamed onto the retina as an inverted image. This process occurs through refraction. DelMonte and Kim (2011) stated that the cis-retina, which are molecules on the retina, absorbs this light only at specified wavelengths. Afterward, the optic neural system takes the images to the brain for interpretation. The brain is the organ which then translates signals into the images that people can then recognize (see Appendix A, Figure 1).

The lighting color and lx influence melatonin secretion. According to Chellappa et al. (2011), the light of higher illuminance (higher lx) inhibits the secretion of melatonin, thus making a person stay awake. When the lx is lower, the secretion of melatonin is higher (Chellappa et al., 2011). The color of light also affects melatonin secretion. A higher wavelength causes higher levels of melatonin secretion (see Appendix A, figure 2).

2.5 The importance of CCT and Lx

A fluorescent lamp is a component that produces light by using fluorescence. The mechanism behind the action of a fluorescent light involves passing current through mercury gas within a phosphor-wrapped tube (Alvarez-Ciacoya et al., 2011). When an electric current is passed through the tube, the mercury vapor then produces ultraviolet radiation, whose wavelength is short (Alvarez-Ciacoya et al., 2011). The radiation then comes into contact with the phosphor coating on the tube, leading to it producing light by glowing (Alvarez-Ciacoya et al., 2011). The CCT for fluorescent lamps varies. Light in these lamps come from the mercury vapor and phosphor coating. It should also be noted that these lamps have CCTs, which vary based on the manufactures. However, they mostly range from 2700 K to 6500 K, depending on the intended use (Alvarez-Ciacoya et al., 2011). The same also applies to the luminance of the lamps. The lx varies, depending on the use for which the lamps are intended.

According to Fotios (2017), the Kruithof curve is a graphical representation of illuminances together with color temperatures, which are perceived by the human eye to be normal, or just comfortable. The curve has illuminance plotted against color temperature. Illuminance is on the y-axis while the x-axis has color temperature (Figure 2.6). The area within the curve is considered normal and comfortable while the area which is outside the curve is uncomfortable for the human eye. The curve was named after Kruithof, the Dutch person who first came up with it. According to Fotios (2017), any lighting which is normal to the observer will fall within the curve. Lighting with higher CCT, like natural light, falls within the curve. However, lighting with tones of blue and red appears in regions that are outside the curve.

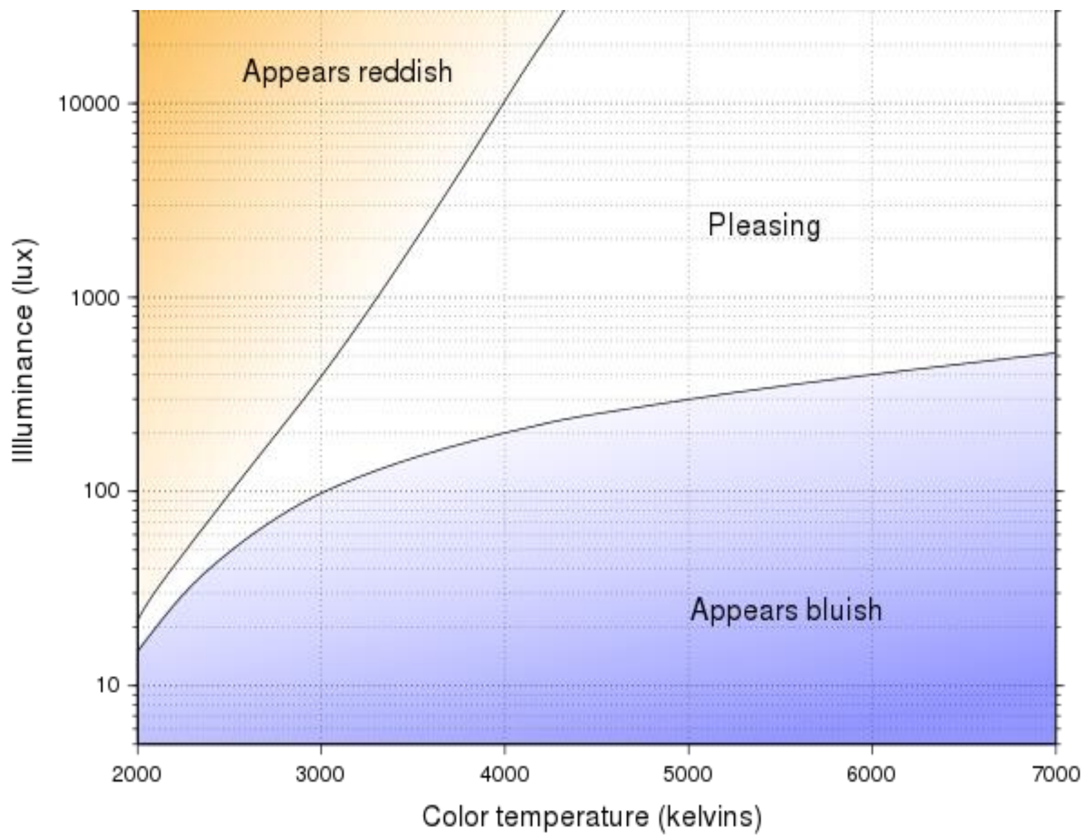


Figure 2.6: Kruithof Curve. The unshaded region is considered a pleasant comfort area, and the shaded area represents the unpleasant region (Fotios, 2017).

The Kruithof curve has been revised over the years to include elements that were criticized in the initial curve presented by Kruithof (Fotios, 2017). In the revised curve (Figure 2.7), illuminance is still plotted on the y-axis against color temperature on the x-axis. However, the difference is that unlike the initial curve there is no curve denoting the region of comfort to an observer. Color temperature in the graph ranges from 2000 to 8000 K. Illuminance, on the other hand, ranges from 5 to 50000. The area in focus is the revised curve, which falls under illuminance of 500 lx (Fotios, 2017). Any area under that shaded region is considered to be the region of discomfort. This is what sets the revised curved apart from the initial curve.

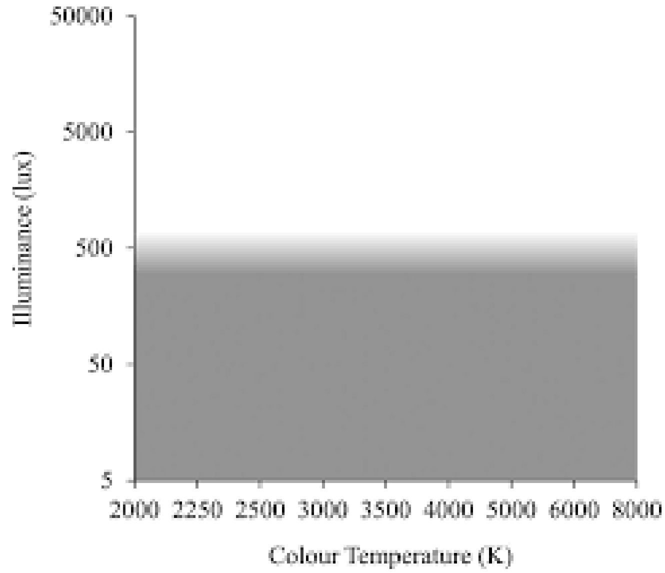


Figure 2.7: The revised Kruithof curve. The shaded region represents unpleasant, and the clear region represents pleasant and comfort (Fotios, 2017).

2.6 Defining Mood in The Educational Sector

The clear meaning of mood still remains elusive despite decades of various research conducted by different scholars. Lynden (2016) views mood as a fundamental aspect of human experience. In his analysis of the mood of an individual, Lynden (2016) outlines some of the types of mood which include anxiety, excitement, and hopefulness. Lynden (2016) also explains that the mood plays an important role in how people spend their time each day in workstations, classes, or just within the house.

The learning sector is a complex institution as both the learner and the teacher are required to have a sober mood. Negative mood leads to undesirable effects on learning activities, which is likely to influence the overall performance. Thus, it is important to know the proper definition of mood. According to Pathak et al. (2011), mood "colors one's thought and pervade one's reflection". This definition is supported by Frijda (2009), who describes mood as an "appropriate destination for affective states that are about nothing specific or about the world in general" (p. 258). Mood has also been described as "feelings that tend to be less intense than emotions, and that often lack a contextual stimulus (as cited in Hume, 2012). Morris and Schnurr (1990) defined mood as "affective states that are capable of influencing a broad array of potential responses, many of which seem quite unrelated to the mood-precipitating event" (p. 14). Hence, it is important to have a positive mood, especially in educational institutions.

Sottilare and Proctor (2012) asserts that all people require a positive mood to think, solve a problem, and remain focused. The authors further stated the importance of positive mood in the learning sector by explaining that the human mind should remain focused in order to learn something. Notably, a positive mood further improves the learner's ability to understand information taught or read in class. Conversely, Sottilare and Proctor (2012) outlined that a negative mood is likely to trigger negative energy among the learners. In such a situation, students tend to feel sad, which affects their concentration level as they are easily disrupted by external factors (Ibid).

2.6.1 Mood (Positive and Negative Affect Schedule)

Watson et al. (1988) established the positive and negative affect schedule (PANAS) questionnaire to measure two main directions of mood: positive and negative affect. The PANAS questionnaire can be used from the present moment (what the participant feels at the present moment) to general (what the participant feels this way on the average) determined by the instructions (Ibid). The PANAS test consists of 20 items divided equally as a positive (10 items) or negative (10 items) affect. The participant would evaluate the object in the questionnaire on a 5-point scale: 1) very slightly or not at all, 2) a little, 3) moderately, 4) quite a bit, and 5) extremely. The scores of the test range from 10 to 50 for positive affect (PA) and negative affect (NA) (Lopez et al., 2016).

David Hume (2012) categorized the positive and negative affect into four aspects: high PA, low PA, high NA, and low NA (Figure 2.8). High positive affect includes alert, excited, elated, and happy. Content is somewhat between the high positive affect and low negative affect, which includes serene, relaxed, calm. On the other hand, high negative affect involves tense, nervous, stressed, and upset. Sad is the mixture between the high negative affect and low positive affect, which contains depressed, bored, and fatigued. These 16 different feelings are answered by the participants to generate the overall mood of the group.

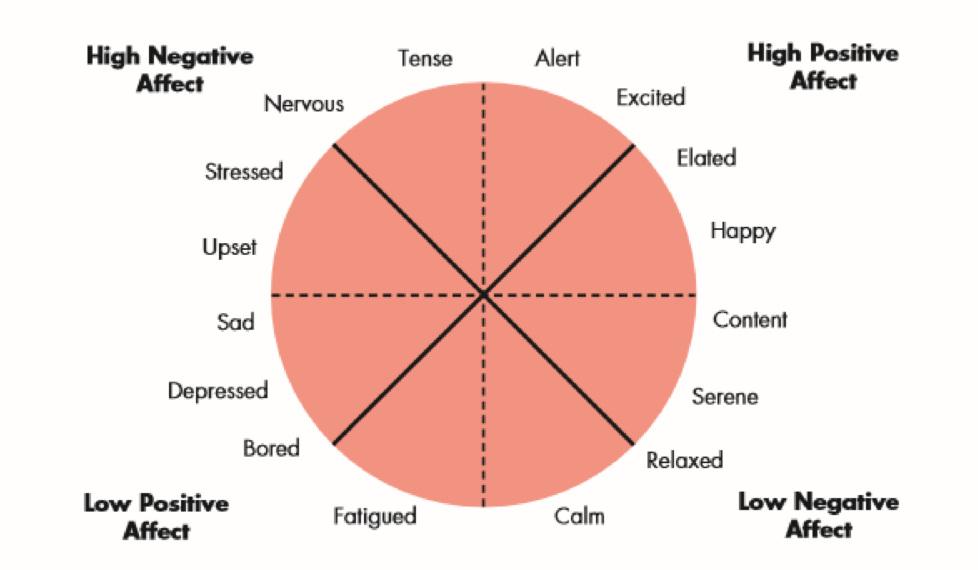


Figure 2.8: The four aspects are high PA, low PA, high Na, and low NA (Hume, 2012).

This research will use the PANAS test developed by Watson et al. (1988) as shown in figure 2.9. However, the words in the PANAS test will be translated into Arabic using the PANAS-D (see Appendix A, Figure 3).

The PANAS

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent [INSERT APPROPRIATE TIME INSTRUCTIONS HERE]. Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

_____ interested	_____ irritable
_____ distressed	_____ alert
_____ excited	_____ ashamed
_____ upset	_____ inspired
_____ strong	_____ nervous
_____ guilty	_____ determined
_____ scared	_____ attentive
_____ hostile	_____ jittery
_____ enthusiastic	_____ active
_____ proud	_____ afraid

We have used PANAS with the following time instructions:

Moment (you feel this way right now, that is, at the present moment)

Figure 2.9: The PANAS test of Watson (Watson et al., 1988).

2.6.2 Mood and Lighting

Generally, lighting affects the mood of every individual independently. Hence, lighting experiments seek to answer if lighting affects the human mood significantly. In a research study conducted by Kuller et al. (2006), mood was examined in a real environment in different seasons and countries. The 988 participants were considered altogether, and the results indicated that lighting conditions of the office environment have an effect on the mood of the participants. The author found that the mood of an individual tends to be strong in a brighter environment. In contrast, insufficient light was associated with negative mood. Elements of negative mood commonly experienced include depression, drowsiness, and laziness. However, bright light as outlined by the authors was found to have a positive impact on productivity (Kuller et al., 2006). Poor lighting, on the other hand, was associated with cognitive disorders. For instance, poor lighting normally affects the eyes of an individual, and its extreme effects may cause strong migraine, leading to difficulties with focusing. Notably, the authors clarify that as far as bright light is effective in maximizing the mood, too much light is also detrimental and may result in drowsiness (Ibid).

Knez and Kers (2000) experiment consisted of 80 participants under two lighting conditions: 4000 K and 3000 K both at 500 lx. These participants were divided randomly, according to their gender and age. The participants were informed about the aim of the experiment, which lasted for 120 minutes. The authors concluded that younger participants preserve the negative effect best in 3000 K and least in 4000 K. The findings also indicated that mood is affected by the differences in age and gender on these different lighting set-ups. Knez (1995) also found similar results of mood being influenced by gender.

Zhu et al. (2017) assert that higher CCT with high illuminance affects mood positively; the participants of this study felt less sleepy. However, Baron et al. (1992) conducted three studies with different lighting conditions to investigate participants' moods. The first two studies revealed that the participants felt more positive in warm light than cool white and in low illuminance than high. The participants in the third study reported feeling "calmer & less tense" at warm, low conditions than at warm, high conditions.

Smolders and Kort (2017) experimented with 39 participants under two conditions: 2700 K and 6000 K both at 500 lx. The study investigated CCT on "individuals experience, performance, and physiology." The result indicates that participants felt more positive in 2700 K compared to 6000 K.

On the other hand, Veitch (1997) experimented with 208 participants (104 male and 104 female) under full-spectrum or cool-white fluorescent lighting. The results did not indicate any significant results for lamp type on mood and performance. Moreover, similar results concluded that CCT had no effect on mood (Boyce and Rea, 1994; Borary et al., 1989).

2.7 The Importance of Attention in the Educational Sector

Attention is generally defined as the act of fixing the mind on something. For example, an individual can be attentive through watching and listening to something. Different types of attention include sustained attention, selective attention, divided attention, and others. Commodari (2017), in her article, identified some of the key aspects of different types of attention. In her analysis, Commodari defined sustained attention as the ability to maintain focus on a given stimulus. Focus is an important element of sustained attention. Technically, focus as a component of sustained attention refers to the ability to respond discretely to a specific stimulus (Commodari, 2017). Focus attention is an interference, for example, a doorbell chime or ringing phone, something that appears for a "period of sustained attention" (as cited in Gerschler, 2012). Focus attention, like any other element of attention, plays a significant role in human cognitive development. As highlighted by Commodari (2017), focus attention enables an individual to reason positively and remain attentive in solving problems.

Attention is an important factor in the learning process. Sustained attention plays a pivotal role in enabling learners to grasp ideas from their teachers (Saez et al., 2012). In order to improve sustained attention in the education sector, stakeholders should carry out extensive research on proper ways to improve the attention of learners. Saez et al. (2012) assert that the learning environment plays an important role in improving the attention level of learners.

In their study, the authors suggested that teachers or any other key stakeholders in the education sector should consider a productive environment for learners.

Hence, teaching and learning depend on sustained attention. Students with a high level of ability to sustain attention always perform well in their respective schools (Saez et al., 2012). Such students are capable of doing even more complex tasks in their research activities. Basically, teachers among stakeholders in the education sector should always strive to enrich learners with opportunities for independent learning. Learning independently tends to maximize the concentration level; thus, it improves learners' ability to sustain attention.

2.7.1 D2 Test of Attention

The d2 test of attention, according to Brickenkamp and Zillmer (1998), is a timed test of selective attention. It quantifies the process speed and quality of performance, taking into consideration an estimation of individual attention and concentration performance (Ibid). Brickenkamp and Zillmer (1998) assert that the d2 test of attention is used by a great number of researchers in several fields.

The d2 test of attention is a five-minute test, consisting of fourteen lines, each with 47 characters of d's and p's that range from one to four dashes per character (Figure 2.10). The subjects should cross out all the d's with two dashes only and are allowed only 20 seconds per line (Ibid). The instructions and a practice line example are given to the participants before the test.

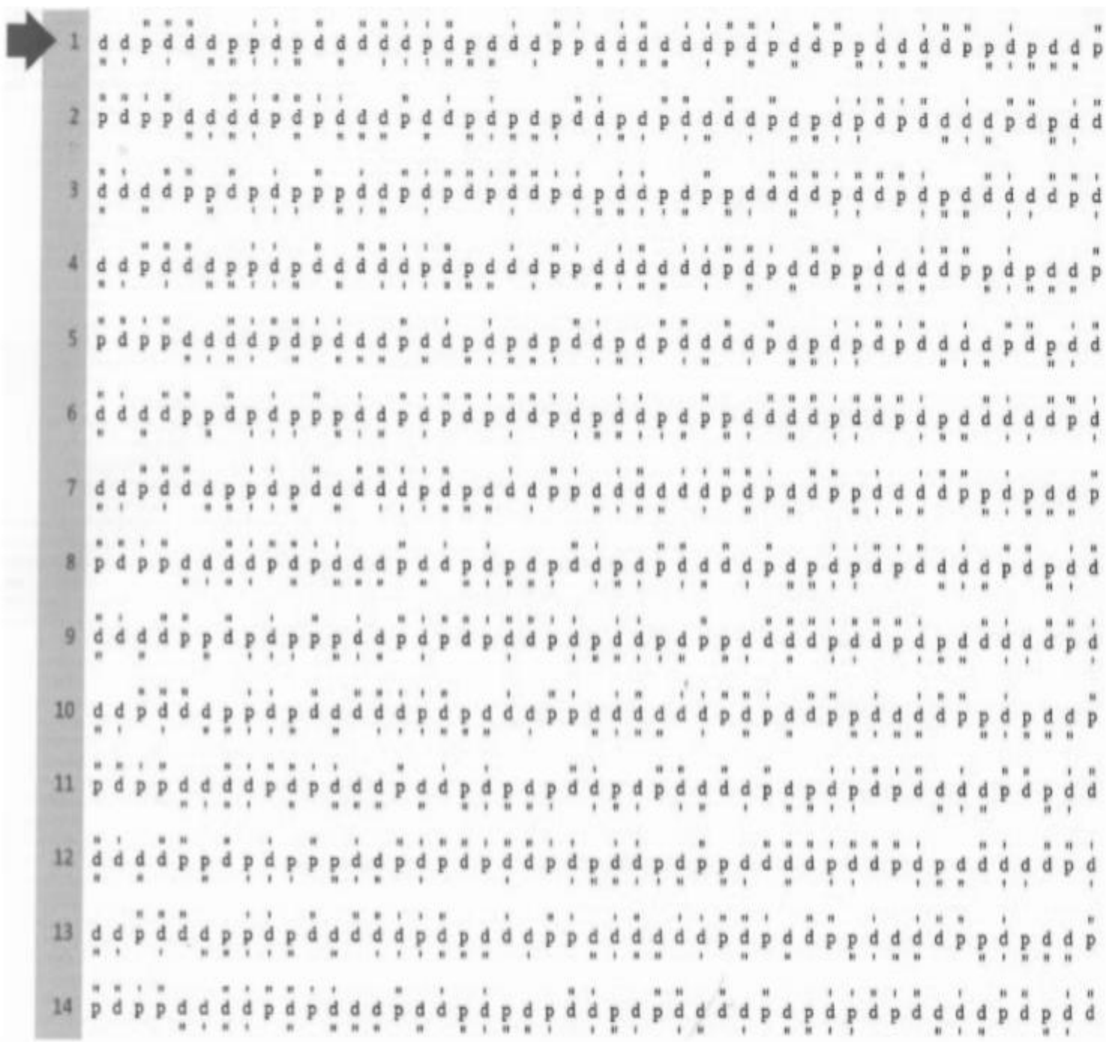


Figure 2.10: The d2 test of attention (Ibid).

Brickenkamp and Zillmer (1998) provided the following meaning scores of the d2 test of attention.

1- TN (speed): the total number of items processed
2- EO (error of omission): when the participant did not cross out the relevant item (d with two dashes)
3- EC (error of commission): when the participant crosses out the irrelevant letters
4- E% (percentage of error): the percentage of the total errors within the total items processed
5- CP (concentration performance): the number of correct items minus the error of commission
6- FR (fluctuation rate) is the difference of the minimum and maximum lines of the total number of items processed. This is the less reliable measure of the d2 test of attention.
7- TN-E (number of items processed minus the total errors) may tend to overestimate the total performance, so CP is recommended for estimating concentration.

2.7.2 Attention and Lighting

Lighting is an important determinant of sustained attention. Studies have been conducted to determine the proper lighting that is likely to improve performance in sustained attention. In their study, Kretschmer et al. (2011) found that bright light tends to improve the cognitive performance of learners. The authors further alluded to the fact that bright light tends to improve the visual performance, and consequently a clear visual performance will make the learner attentive during the learning process (Kretschmer et al., 2011).

Yea Shin et al. (2013) investigated different lighting conditions. The authors assert that the lighting condition of higher CCT and lx (6600 K, 800 lx) improved the attention level compared with the existing lighting conditions (4000 K, 500 lx). The result of this study is supported by Pulay et al. (2018), who concluded that students under high CCT display more on-task behaviors. In addition, Chellappa et al. (2011) compared three different lighting conditions: 6500 K, 2500 K, and 3000 K. The authors concluded that 6500 K lighting conditions induced greater melatonin suppression with greater subjective alertness and visual comfort. The study also found that the reaction of the participants in the 6500 K condition is faster in tasks that involve sustained attention.

Shamsul et al. (2013) conducted a study that investigated the effects of warm white light (WWL) at CCT 3000 K, cool white light (CWL) at CCT 4000 K, and artificial daylight (DL) at CCT 6500 K on 47 students' performance and comfort level. The authors found that both 4000 K and 6500 K impact student alertness level and academic activities positively for both computer-based and paper-based activities.

Smolders (2012) investigated the effects of two lighting conditions (200 lx and 1000 lx) at eye level both at 4000 K on a mixed-group design (N= 32, 82 sessions). The author found that higher illuminance improved subjective alertness and vitality. The study also indicated that exposure to a high illuminance may affect “brain activity immediately during regular daytime hours” (Smolders, 2012).

Three Dutch studies conducted by Sleegers et al. (2012) investigated the effect of lighting conditions on student concentration. The authors conclude that the lighting system affects student concentration and underlined the importance of lighting in the educational sector. Morrow and Kanakri (2018) examined the effect of high CCT of both LED and fluorescent lighting through a survey for children (5 to 14 years). The authors assert that the result supports the 5000 K or higher CCT lighting conditions, which affect the alertness, focus, and performance of the participants positively.

On the other hand, the three studies of Baron et al. (1992) produced contrary results. Two studies found that the participants reported more positive reaction when exposed to low CCT rather than high CCT, and to low illuminance rather than high illuminance. In addition, the third study supports the finding of the first two studies by concluding that participants felt calmer and less tense in warm-light, low illuminance compared to warm-light, high illuminance. Borisuit et al. (2014) assert that the participants in their study felt less alertness at high CCT in the first half of the afternoon. Moreover, Boyce et al. (2006) concluded that there were no significant effects of lighting quality on the performance of their two experiments.

CHAPTER 3

THE EXPERIMENT METHODOLOGY

3.1 Aim of the Study

This research aims to investigate the effects of the illuminance and CCT relationship on student attention and mood. The result of this research will be compared between the Kruithof graph and the revised Kruithof graph.

3.1.1 Research Questions

1- Is there a significant effect of the correlated color temperature of lighting on sustained attention levels of the university students in terms of the following: (comparing 6500 K, 4600 K, 2700 K, 300 lx)

   a- concentration performance (CP)

   b- number of errors (E%)

2- Is there a significant effect of the illuminance of lighting on sustained attention levels of the university students in terms of the following: (comparing 6500 K, 300 lx and 6500 K, 600 lx)

   a- Concentration performance (CP)

   b- Number of errors (E%)

3- Is there a significant effect of the combination of illuminance and correlated color temperature of lighting on sustained attention levels of the university students in terms of the following: (comparing all six conditions)

   c- Concentration performance (CP)

   d- Number of errors (E%)

4- Is there a significant effect of correlated color temperature/ illuminance of lighting on student mood?

3.1.2 Hypothesis

1- CP (concentration performance) values are higher in 6500 K, 300 lx condition compared to 4600 K, 300 lx, and 2700 K, 300 lx.

2- E% of the d2 test of attention decreases at 6500 K compared to 4600 K and 2700 K all at 300 lx.

3- CP (concentration performance) increases at the highest CCT and illuminance condition (6500 K, 600 lx) compared to 4600 K and 2700 K all at 600 lx.
4- E% of the d2 test of attention decreases at 6500 K compared to 4600 K and 2700 K at (600 lx).

5- CP (concentration performance) values are higher in 6500 K, 600 lx than all other conditions.

6- E% of the d2 test of attention is lower at 6500 K, 600 lx than all other conditions.
7- Student's PA (positive affect) in the mood test increases at the highest CCT and illuminance (6500 K, 600 lx).

3.2 The Methodology of the Experiment

The experiment will be performed six times, each one with a different condition as shown below.

1- The students are tested under 6500 K, 300 lx.
2- The students are tested under 6500 K, 600 lx.
3- The students are tested under 4600 K, 300 lx.
4- The students are tested under 4600 K, 600 lx.
5- The students are tested under 2700 K, 300 lx.
6- The students are tested under 2700 K, 600 lx.

3.2.1 Group Sample

The experiment consisted of 18 undergraduate students (87.5% female) from the Architecture Department at Kuwait University. The course that was chosen in the 2018-2019 Fall semester consisted of more than 18 students. However, all students that did not participate in all the conditions were excluded from the group sample (conducted within subject) as shown in table 3.1.

Group								
Condition	Number	Male	%	Female	%	Age		
						Min	Max	AVG
1	18	2	12.5	16	87.5	20	24	21
2	18	2	12.5	16	87.5	20	24	21
3	18	2	12.5	16	87.5	20	24	21
4	18	2	12.5	16	87.5	20	24	21
5	18	2	12.5	16	87.5	20	24	21
6	18	2	12.5	16	87.5	20	24	21

Table 3.1: The summary of the paired group sample

3.2.2 The Experimental Set-up

The experiment was done at three different lecture dates of the chosen course. The classroom size of the chosen course is 5.7m x 11m x 3.60m. The walls and the 60 x 60 ceiling are white, but the curtain of the left wall is blue (see Appendix B, Table 1). Furthermore, the reflectance of the wall is about 58%, while the curtain reflectance is 16% (see Appendix B,

Table 2). The daylight in the classroom is totally prevented by the curtains in order to test the impact of CCT and lx on student mood and attention without interfering with daylight. In addition, each subject was assigned a specific number of their seating position in order to maintain the exact seating position in all conditions (Figure 3.1). The classroom consisted of thirty 60 x 60 recessed luminaires (18 old and 12 new) that consisted of four fluorescent lighting fixtures (see Appendix B, Figure 1). The existing lighting fixture was replaced with a Toshiba FL20T8WW/18W fluorescent lamp (2700 K), a Toshiba FL20T8D/18W fluorescent lamp (6500 K), and the 4600 K were achieved by mixing two lighting fixtures of the fluorescent lamp of each 2700 K and 6500 K (Figure 3.2).

Figure 3.1: All the available seats in the classroom. The seats of the students that participated in all conditions are highlighted red.

Figure 3.2: The three lighting CCT set-ups during the beginning of the lecture. A is the daylight condition 6500 K, while B is the cool white 4600 K, and C is the warm white 2700 K.

The experiment set-up was identical for all conditions in terms of seating, HVAC, student, and preventing of daylight. However, the differences in the conditions are the different CCT and lx, as mentioned in the methodology. The first lighting setup was set to 6500 K (Daylight), on the second lighting setup was set to 4600 K (Cool White), and the last lighting setup was set to 2700 K (Warm White). Moreover, three conditions were higher in terms of illuminance that was achieved by installing additional twelve 60 x 60 recessed fluorescent luminaires in the classroom. The illuminance was measured by the light meter

(Testo-545) (see Appendix B, figure 2). The average recorded value of the illuminance for all conditions (above 0.68 m floor) is as shown below:

1- Condition 1: 6500 K, 305 lx (see Appendix B, Table 3)
2- Condition 2: 6500 K, 613 lx (see Appendix B, Table 3)
3- Condition 3: 4600 K, 298 lx (see Appendix B, Table 4)
4- Condition 4: 4600 K, 605 lx (see Appendix B, Table 4)
5- Condition 5: 2700 K, 299 lx (see Appendix B, Table 5)
6- Condition 6: 2700 K, 609 lx (see Appendix B, Table 5)

The Experiment										
	Date	Class Time		Time Line						
				PANAS (BEFORE)		D2 TEST		PANAS (AFTER)		
Condition 1	Thursday, 21th November 2018	13:50	15:20	13:55	14:00	14:10	14:17	14:25	14:30
Condition 2	Thursday, 21th November 2018	13:30	15:20	14:40	14:45	14:55	15:02	15:15	15:20
Condition 3	Tuesday, 26th November 2018	13:50	15:20	13:55	14:00	14:10	14:17	14:25	14:30
Condition 4	Tuesday, 26th November 2018	13:30	15:20	14:40	14:45	14:55	15:02	15:15	15:20
Condition 5	Thursday, 28th November 2018	13:50	15:20	13:55	14:00	14:10	14:17	14:25	14:30
Condition 6	Thursday, 28th November 2018	13:30	15:20	14:40	14:45	14:55	15:02	15:15	15:20

Table 3.2: The Summary of the time-line of the experiment.

The six conditions were conducted on three different dates; two conditions each lecture (Table 3.2). The timeline of each condition is around forty minutes, with ten minutes break to switch from condition A to condition B by turning on the switch of the installed luminaire. The subjects were seated accordingly to their number that was given prior to the first condition. The lecture was divided into two different conditions. The subjects started with the PANAS -paper-based of the first condition to test mood at that moment and then the regular lecture started. Additionally, the d2 test of attention- paper-based were given in the middle of the lecture and at last, the PANAS test- paper-based were given to compare the mood (before/after) of the first condition. Then the professor continues to explain the class material to the student while turning on to the new condition (higher illuminance). The same procedure in condition one is repeated in condition two (Table 3.2). The experiment was repeated within subject for the other conditions on Tuesday, November 26th, 2018 and on Thursday, November 28th, 2018.

CHAPTER 4

THE EXPERIMENT RESULT

4.1 Experiment Statistical Analysis

Statistical Package of Social Sciences (SPSS) from IBM (version 24) was used in this research to measure and analyze the collected data. The tests that were used to analyze the data are as shown below;

1- Anova Repeated Measure (comparing CP and E%).

2- T-test (comparing (CP & E%), and PA (before/after)).

3- Pearson's correlation test.

4.2 First Phase: Analysis of D2 test of attention

The effects of the CCT and Lx that were used in the six conditions on student's attention were compared among the d2 test of attention results:

1- TN= Speed "number of items processed"

2- EO= Error omission

3- EC= Error commission

4- E%= Error percentage = ((EO+EC)/(TN)) *100

5- CP= Concentration performance

Moreover, a protected dependent t-test was used with repeated measure ANOVA because the ANOVA results were significant for all six conditions (see Appendix C, Table 1).

4.2.1. Analysis of the three CCT conditions at 300 Lx

4.2.1.1 TN: SPEED "number of items processed"

6500K/4600K/2700K		N	Mean	STD	t	Df	Sig
TN#1	6500 K	18	521.278	70.445	-1.808	17	0.088
	4600 K	18	549.722	74.976			
TN#2	6500 K	18	521.278	70.445	-3.687	17	0.002
	2700 K	18	568.055	76.925			
TN#3	4600 K	18	549.722	74.976	-1	17	0.331
	2700 K	18	568.055	76.925			

Table 4.1: A table showing the "TN" mean values and the outcomes of t-test (6500 K, 4600 K, and 2700 K CCT) at 300 Lx.

The t-test indicated that, the effect of CCT at 300 Lx on the "TN" was not significant in the scores for 6500 K (M=521.3, SD=70.4) and 4600 K (M= 549.7, SD= 75) conditions; t (17) = -1.808, p= 0.088; and the scores for 4600 K (M=549.7, SD= 75) and 2700 K (M=568, SD= 77) conditions; t(17)= -1, p= 0.331 (see Appendix C, table 2). Therefore, CCT does not have an effect on student's speed to scan the total number of items in d2 test of attention.

However, there was a significant difference in the score for 6500 K (M=521.3, SD= 70.4) and 2700 K (M=568, SD=77) conditions; t (17) = -3.68, p= 0.002 (see Appendix C, Table 2). Therefore, 2700 K enhances student ability to scan the items in the d2 test of attention than 6500 K.

4.2.1.2 EO: Error of Omission

6500K/4600K/2700K		N	Mean	STD	t	df	Sig
EO#1	6500 K	18	34.2778	15.58	-2.639	17	0.017
	4600 K	18	40.0556	17.965			
EO#2	6500 K	18	34.2778	15.58	-3.211	17	0.005
	2700 K	18	51.166	27.53			
EO#3	4600 K	18	40.0556	17.965	-2.084	17	0.053
	2700 K	18	51.166	27.53			

Table 4.2: A table showing the “EO” mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 300 Lx.

The t-test indicated that, the effect of CCT at 300 Lx on the “EO” was a significant in the scores for 6500 K (M=34.3, SD=15.6) and 4600 K (M= 40.05, SD= 18) conditions; t (17) = -2.639, p= 0.017; and the scores for 6500 K (M=34.3, SD=15.6) and 2700 K (M=51.16, SD= 27) conditions; t(17)= -3.211, p= 0.005 (see Appendix C, table 3). Therefore, CCT have an effect on student’s error omission in d2 test of attention.

However, there was no significant difference in the scores for 4600 K (M= 40.05, SD= 18) and 2700 K (M=51.16, SD= 27) conditions; t (17) = -2.084, p= 0.053 (see Appendix C, table 3). Therefore, CCT does not have an effect on student's error of omission in d2 test of attention.

4.2.1.3 EC: Error of Commission

6500K/4600K/2700K		N	Mean	STD	T	Df	Sig
EC#1	6500 K	18	0.6667	0.84017	-1.583	17	0.132
	4600 K	18	1.6111	2.4043			
EC#2	6500 K	18	0.6667	0.84017	-3.465	17	0.003
	2700 K	18	2.3889	1.61387			
EC#3	4600 K	18	1.6111	2.4043	-1.137	17	0.271
	2700 K	18	2.3889	1.61387			

Table 4.3: A table showing the "EC" mean values and the outcomes of the t-test (6500 K, 4600 K, and 2700 K CCT) at 300 Lx.

The t-test indicated that, the effect of CCT at 300 Lx on the "EC" was not significant in the scores for 6500 K (M=0.67, SD=0.84) and 4600 K (M= 1.61, SD= 2.40) conditions; t (17) = -1.583, p= 0.132; and the scores for 4600 K (M=1.61, SD= 2.40) and 2700 K (M=2.39, SD= 1.61) conditions; t(17)= -1.137, p= 0.271 (see Appendix C, table 4). Therefore, CCT does not have an effect on student's error of commission in d2 test of attention.

However, there was a significant difference in the scores for 6500 K (M=0.67, SD= 0.84) and 2700 K (M=2.39, SD=1.61) conditions; t (17) = -3.465, p= 0.003 (see Appendix C, table 4). Therefore, 2700 K increases students' error of commission in d2 test of attention than 6500 K.

4.2.1.4 E%: Error Percentage

6500K/4600K/2700K		N	Mean	STD	t	Df	Sig
E%#1	6500 K	18	6.5667	2.4793	-3.33	17	0.004
	4600 K	18	7.4389	2.8718			
E%#2	6500 K	18	6.5667	2.4793	-3.401	17	0.003
	2700 K	18	9.2278	4.2846			
E%#3	4600 K	18	7.4389	2.8718	-2.192	17	0.043
	2700 K	18	9.2278	4.2846			

Table 4.4: A table showing the "E%" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 300 Lx.

The t-test indicated that, the effect of CCT at 300 Lx on the "E%" was significant in all three comparison; the scores for 6500 K (M=6.6, SD=2.5) and 4600 K (M= 7.4, SD= 2.9) conditions; t (17) = -3.33, p= 0.004; and the scores for 4600 K (M=7.4, SD= 2.9) and 2700 K (M=9.2, SD= 4.3) conditions; t(17)= -2.192, p= 0.043; and the scores for 6500 K (M=6.6, SD=2.5) and 2700 K (M=9.2, SD= 4.3) conditions; t(17)= -3.401, p= 0.003 (see Appendix

C, table 5). Therefore, CCT have an effect on student's error percentages in d2 test of attention. The lowest E% is at 6500 K and the highest E% is at 2700 K.

4.2.1.5 CP: Concentration performance

6500K/4600K/2700K		N	Mean	STD	t	df	Sig
CP#1	6500 K	18	189.778	31.9403	-1.32	17	0.204
	4600 K	18	199.111	32.725			
CP#2	6500 K	18	189.778	31.9403	-1.366	17	0.19
	2700 K	18	198.5	38.14			
CP#3	4600 K	18	199.111	32.725	0.068	17	0.947
	2700 K	18	198.5	38.14			

Table 4.3: A table showing the "CP" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 300 Lx.

The t-test indicated that, the effect of CCT at 300 Lx on the "CP" was not significant in all three comparison; the scores for 6500 K (M=189.8, SD=32) and 4600 K (M= 199.1, SD= 33) conditions; t (17) = -1.32, p= 0.204; and the scores for 4600 K (M=199.1, SD= 33) and 2700 K (M=198.5, SD= 38) conditions; t(17)= 0.068, p= 0.947; and the scores for 6500 K (M=189.8, SD=32) and 2700 K (M=198.5, SD= 38) conditions; t(17)= -1.366, p= 0.19 (see Appendix C, table 6). Therefore, CCT does not have an effect on student's concentration performance in d2 test of attention.

4.2.2 Analysis of the three CCT conditions at 600 Lx

4.2.2.1 TN: SPEED "number of items processed"

6500K/4600K/2700K		N	Mean	STD	t	df	Sig
TN#1	6500 K	18	585.55	64.3	-1.308	17	0.208
	4600 K	18	599.83	57.72			
TN#2	6500 K	18	585.55	64.3	-0.524	17	0.607
	2700 K	18	593.44	68.47			
TN#3	4600 K	18	599.83	57.72	0.424	17	0.677
	2700 K	18	593.44	68.47			

Table 4.6: A table showing the "TN" mean values and the outcomes of t-test (6500 K, 4600 K, and 2700 K CCT) at 600 lx.

The t-test indicated that, the effect of CCT at 600 lx on the "TN" was not significant in all three comparison; the scores for 6500 K (M=585.5, SD=64.3) and 4600 K (M= 599.8, SD= 57.7) conditions; t (17) = -1.308, p= 0.208; and the scores for 4600 K (M=599.8, SD= 57.7) and 2700 K (M=593.4, SD= 68.47) conditions; t(17)= 0.424, p= 0.677; and the scores for 6500 K (M=585.5, SD=64.3) and 2700 K (M=593.4, SD= 68.47) conditions; t(17)= -0.524, p= 0.607 (see Appendix C, table 7). Therefore, CCT does not have an effect on student's speed to scan the items on d2 test of attention.

4.2.2.2 EO: Error of Omission

6500K/4600K/2700K		N	Mean	STD	t	df	Sig
EO#1	6500 K	18	22.055	14.139	-3.931	17	0.001
	4600 K	18	28.888	13.616			
EO#2	6500 K	18	22.055	14.139	-2.345	17	0.031
	2700 K	18	31.388	19.33			
EO#3	4600 K	18	28.888	13.616	-0.633	17	0.535
	2700 K	18	31.388	19.33			

Table 4.7: A table showing the "EO" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 600 Lx.

The t-test indicated that, the effect of CCT at 600 Lx on the "EO" was significant in the scores for 6500 K (M=22.05, SD=14.14) and 4600 K (M= 28.88, SD= 13.62) conditions; t (17) = -3.931, p= 0.001; and the scores for 6500 K (M=22.05, SD= 14.14) and 2700 K (M=31.38, SD= 19.33) conditions; t(17)= -2.345, p= 0.031 (see Appendix C, table 8). Therefore, CCT have an effect on student's error of omission in d2 test of attention at those conditions.

However, there was no significant difference in the scores for 4600 K (M= 28.88, SD= 13.62) and 2700 K (M=31.38, SD= 19.33) conditions; t (17) = -0.633, p= 0.535 (see Appendix C, table 8). Therefore, CCT have no effect on student's error of omission in d2 test of attention between 4600 K and 2700 K.

4.2.2.3 EC: Error of Commission

6500K/4600K/2700K		N	Mean	STD	t	df	Sig
EC#1	6500 K	18	0.6111	0.6978	-1.065	17	0.302
	4600 K	18	0.9444	1.1099			
EC#2	6500 K	18	0.6111	0.6978	-2.06	17	0.055
	2700 K	18	1.333	1.236			
EC#3	4600 K	18	0.9444	1.1099	-1.046	17	0.31
	2700 K	18	1.333	1.236			

Table 4.8: A table showing the "EC" mean values and the outcomes of the t-test (6500 K, 4600 K, and 2700 K CCT) at 600 lx.

The t-test indicated that, the effect of CCT at 600 Lx on the "EC" was not significant in all three comparison; the scores for 6500 K (M=0.611, SD=0.69) and 4600 K (M= 0.944, SD= 1.10) conditions; t (17) = -1.065, p= 0.302; and the scores for 4600 K (M=0.944, SD= 1.10) and 2700 K (M=1.333, SD= 1.236) conditions; t(17)= -1.046, p= 0.31; and the scores for 6500 K (M=0.611, SD=0.69) and 2700 K (M=1.333, SD= 1.236) conditions; t(17)= -2.06, p= 0.055 (see Appendix C, table 9). Therefore, CCT does not have an effect on student's error of commission on d2 test of attention.

4.2.2.4 E%: Error Percentage

6500K/4600K/2700K		N	Mean	STD	t	df	Sig
E%#1	6500 K	18	3.777	2.238	-3.988	17	0.001
	4600 K	18	4.888	2.0395			
E%#2	6500 K	18	3.777	2.238	-2.83	17	0.012
	2700 K	18	5.5	3.114			
E%#3	4600 K	18	4.888	2.0395	-1.005	17	0.329
	2700 K	18	5.5	3.114			

Table 4.9: A table showing the "E%" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 600 Lx.

The t-test indicated that, the effect of CCT at 600 lx on the "E%" was significant in the scores for 6500 K (M=3.77, SD=2.238) and 4600 K (M= 4.88, SD= 2.039) conditions; t (17) = -3.988, p= 0.001; and the scores for 6500 K (M=3.77, SD=2.238) and 2700 K (M=5.5, SD= 3.114) conditions; t(17)= -2.83, p= 0.012 (see Appendix C, table 10). Therefore, CCT have an effect on student's error percentage in d2 test of attention at those conditions.

However, there was no significant difference in the scores for 4600 K (M= 4.88, SD= 2.039) and 2700 K (M=5.5, SD= 3.114) conditions; t (17) = -1.005, p= 0.329 (see Appendix C, Table 10). Therefore, CCT have no effect on student's error percentage in d2 test of attention between 4600 K and 2700 K.

4.2.2.5 CP: Concentration performance

6500K/4600K/2700K		N	Mean	STD	t	df	Sig
CP#1	6500 K	18	238	31.293	0.063	17	0.95
	4600 K	18	237.6	28.856			
CP#2	6500 K	18	238	31.293	0.99	17	0.336
	2700 K	18	230.66	38.662			
CP#3	4600 K	18	237.6	28.856	0.849	17	0.408
	2700 K	18	230.66	38.662			

Table 4.10: A table showing the "CP" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 600 lx.

The t-test indicated that, the effect of CCT at 600 Lx on the "CP" was not significant in all three comparison; the scores for 6500 K (M=238, SD=31.29) and 4600 K (M= 237.6, SD= 28.85) conditions; t (17) = 0.063, p= 0.95; and the scores for 4600 K (M= 237.6, SD= 28.85) and 2700 K (M=230.66, SD= 38.66) conditions; t(17)= 0.849, p= 0.408; and the scores for 6500 K (M=238, SD=31.29) and 2700 K (M=230.66, SD= 38.66) conditions; t(17)= 0.99, p= 0.336 (see Appendix C, table 11). Therefore, CCT does not have an effect on student's concentration performance on d2 test of attention.

4.2.3 Analysis of the three (CCT, 300 Lx) vs. (CCT, 600 Lx) conditions

4.2.3.1 TN: SPEED "number of items processed"

Conditions		N	Mean	STD	T	df	Sig
TN#1	6500 K, 300 Lx	18	521.278	70.445	-5.918	17	0.000
	4600 K, 600 Lx	18	599.83	57.72			
TN#2	6500 K, 300 Lx	18	521.278	70.445	-4.805	17	0.000
	2700 K, 600 Lx	18	593.44	68.47			
TN#3	6500 K, 600 Lx	18	585.55	64.3	2.915	17	0.010
	4600 K, 300 Lx	18	549.722	74.976			
TN#4	4600 K, 300 Lx	18	549.722	74.976	-2.259	17	0.037
	2700 K, 600 Lx	18	593.44	68.47			
TN#5	4600 K, 600 Lx	18	599.83	57.72	1.929	17	0.071
	2700 K, 300 Lx	18	568.055	76.925			
TN#6	6500 K, 600 Lx	18	585.55	64.3	1.216	17	0.241
	2700 K, 300 Lx	18	568.055	76.925			

Table 4.11: A table showing the "TN" mean values and the outcomes of t-test of (6500 K, 4600 K, and 2700 K CCT, 300 lx) at (6500 K, 4600 K, 2700 K CCT, 600 lx).

The t-test indicated that, the effect of CCT at 600 lx vs CCT at 300 lx on the "TN" was significant in the scores for 6500 K, 300 lx (M=521, SD=70) and 4600 K, 600 lx (M= 599, SD= 57) conditions; t (17) = -5.918, p= 0.000; and the scores for 6500 K, 300 lx (M=521, SD=70) and 2700 K, 600 lx (M=593, SD= 68) conditions; t(17)= -4.805, p= 0.000; and the scores for 6500 K, 600 lx (M=585, SD= 64) and 4600 K, 300 lx (M=549, SD= 75) conditions; t(17)= 2.915, p= 0.010; and the scores for 4600 K, 300 lx (M=549, SD= 75) and 2700 K, 600 lx (M=593, SD= 68) conditions; t(17)= -2.259, p= 0.037 (see Appendix C, table

12). Therefore, CCT have an effect on student's speed to scan the items in d2 test of attention at those conditions.

However, there was no significant difference in the scores for 4600 K, 600 lx (M= 599, SD= 57) and 2700 K, 300 lx (M=568, SD= 77) conditions; t (17) = 1.929, p= 0.071; and the scores for 6500 K, 600 lx (M=585, SD= 64) and 2700 K, 300 lx (M=568, SD= 77) conditions; t(17)= 1.216, p= 0.241 (see Appendix C, table 12). Therefore, CCT have no effect on student's speed to scan items in d2 test of attention on those conditions. However, the mean of all condition at 600 lx are higher than the conditions at 300 lx.

4.2.3.2 EO: Error of Omission

Conditions		N	Mean	STD	T	df	Sig
EO#1	6500 K, 300 Lx	18	34.2778	15.58	2.229	17	0.040
	4600 K, 600 Lx	18	28.888	13.616			
EO#2	6500 K, 300 Lx	18	34.2778	15.58	0.72	17	0.482
	2700 K, 600 Lx	18	31.388	19.33			
EO#3	6500 K, 600 Lx	18	22.055	14.139	-6.348	17	0.000
	4600 K, 300 Lx	18	40.0556	17.965			
EO#4	4600 K, 300 Lx	18	40.0556	17.965	2.125	17	0.049
	2700 K, 600 Lx	18	31.388	19.33			
EO#5	4600 K, 600 Lx	18	28.888	13.616	-3.89	17	0.001
	2700 K, 300 Lx	18	51.166	27.53			
EO#6	6500 K, 600 Lx	18	22.055	14.139	-4.824	17	0.000
	2700 K, 300 Lx	18	51.166	27.53			

Table 4.12: A table showing the "EO" mean values and the outcomes of t-test of (6500 K, 4600 K, and 2700 K CCT, 300 lx) at (6500 K, 4600 K, 2700 K CCT, 600 lx).

The t-test indicated that, the effect of CCT at 600 lx vs CCT at 300 lx on the "EO" was significant in the scores for 6500 K, 300 lx (M=34.3, SD=15.6) and 4600 K, 600 lx (M= 29, SD= 13.6) conditions; t (17) = 2.23, p= 0.040; and the scores for 6500 K, 600 lx (M=22, SD=14) and 4600 K, 300 lx (M=40, SD= 18) conditions; t(17)= , p= 0.000; and the scores for 4600 K, 300 lx (M=40, SD= 18) and 2700 K, 600 lx (M=31, SD= 19) conditions; t(17)= 2.125, p= 0.049; and the scores for 4600 K, 600 lx (M=29, SD= 13.7) and 2700 K, 300 lx (M=51, SD= 27.5) conditions; t(17)= -3.89, p= 0.001; and the scores for 6500 K, 600 lx (M=22, SD= 14) and 2700 K, 300 lx (M=51, SD= 27.5) conditions; t(17)= -4.82, p= 0.000 (see Appendix C, table 13).

However, there was no significant difference in the scores for 6500 K, 300 lx (M= 34.3, SD= 15.6) and 2700 K, 600 lx (M=31.4, SD= 19.3) conditions; t (17) = 0.72, p= 0.482. Therefore, CCT has no effect on student's error or omission in the d2 test of attention on this condition (see Appendix C, Table 13). However, the mean of all conditions at 600 lx is lower than the conditions at 300 lx.

4.2.3.3 EC: Error of Commission

Conditions		N	Mean	STD	t	df	Sig
EC#1	6500 K, 300 Lx	18	0.6667	0.84017	-0.792	17	0.439
	4600 K, 600 Lx	18	0.9444	1.1099			
EC#2	6500 K, 300 Lx	18	0.6667	0.84017	-1.799	17	0.09
	2700 K, 600 Lx	18	1.333	1.236			
EC#3	6500 K, 600 Lx	18	0.6111	0.6978	-1.715	17	0.104
	4600 K, 300 Lx	18	1.6111	2.4043			
EC#4	4600 K, 300 Lx	18	1.6111	2.4043	0.43	17	0.672
	2700 K, 600 Lx	18	1.333	1.236			
EC#5	4600 K, 600 Lx	18	0.9444	1.1099	-3.25	17	0.005
	2700 K, 300 Lx	18	2.3889	1.61387			
EC#6	6500 K, 600 Lx	18	0.6111	0.6978	-4.85	17	0.000
	2700 K, 300 Lx	18	2.3889	1.61387			

Table 4.13: A table showing the “EC” mean values and the outcomes of t-test of (6500 K, 4600 K, and 2700 K CCT, 300 Lx) at (6500 K, 4600 K, 2700 K CCT, 600 Lx).

The t-test indicated that, the effect of CCT at 600 lx vs CCT at 300 lx on the “EC” was significant in the scores for 4600 K, 600 lx (M=0.94, SD=1.11) and 2700 K, 300 lx (M= 2.4, SD= 1.61) conditions; t (17) = -3.25, p= 0.005; and the scores for 6500 K, 600 lx (M=0.61, SD=0.7) and 2700 K, 300 lx (M=2.4, SD= 1.6) conditions; t(17)= -4.85, p= 0.000 (see Appendix C, table 14).

However, there was no significant difference in the scores for 6500 K, 300 lx (M= 0.67, SD= 0.84) and 4600 K, 600 lx (M=0.95, SD= 1.11) conditions; t (17) = -0.792, p= 0.439;

and the scores for 6500 K, 300 lx (M=0.67 SD= 0.84) and 2700 K, 600 lx (M=1.33, SD= 1.24) conditions; t(17)= -1.799, p= 0.09; and the scores for 6500 K, 600 lx (M=0.61 SD= 0.69) and 4600 K, 300 lx (M=1.61, SD= 2.40) conditions; t(17)= -1.715, p= 0.104; and the scores for 4600 K, 300 lx (M=1.61 SD= 2.40) and 2700 K, 600 lx (M=1.33, SD= 1.24) conditions; t(17)= 0.43, p= 0.672 (see Appendix C, table 14). Therefore, CCT have no effect on student's error of commission in d2 test of attention on those conditions.

4.2.3.4 E%: Error Percentage

Conditions		**N**	**Mean**	**STD**	**t**	**df**	**Sig**
E%#1	6500 K, 300 Lx	18	6.5667	2.4793	4.553	17	0.000
	4600 K, 600 Lx	18	4.888	2.0395			
E%#2	6500 K, 300 Lx	18	6.5667	2.4793	1.821	17	0.086
	2700 K, 600 Lx	18	5.5	3.114			
E%#3	6500 K, 600 Lx	18	3.777	2.238	-7.453	17	0.000
	4600 K, 300 Lx	18	7.4389	2.8718			
E%#4	4600 K, 300 Lx	18	7.4389	2.8718	3.038	17	0.007
	2700 K, 600 Lx	18	5.5	3.114			
E%#5	4600 K, 600 Lx	18	4.888	2.0395	-4.825	17	0.000
	2700 K, 300 Lx	18	9.2278	4.2846			
E%#6	6500 K, 600 Lx	18	3.777	2.238	-5.917	17	0.000
	2700 K, 300 Lx	18	9.2278	4.2846			

Table 4.14: A table showing the "E%" mean values and the outcomes of t-test of (6500 K, 4600 K, and 2700 K CCT, 300 Lx) at (6500 K, 4600 K, 2700 K CCT, 600 Lx).

The t-test indicated that, the effect of CCT at 600 lx vs CCT at 300 lx on the “TN” was significant in the scores for 6500 K, 300 lx ($M=6.6$, $SD=2.5$) and 4600 K, 600 lx ($M= 4.9$, $SD= 2.0$) conditions; $t(17) = 4.553$, $p= 0.000$; and the scores for 6500 K, 600 lx ($M=3.8$, $SD= 2.2$) and 4600 K, 300 lx ($M=7.4$, $SD= 2.9$) conditions; $t(17)= -7.45$, $p= 0.000$; and the scores for 4600 K, 300 lx ($M= 7.4$, $SD= 2.9$) and 2700 K, 600 lx ($M=5.5$, $SD= 3.1$) conditions; $t(17)= 3.04$, $p= 0.007$; and the scores for 4600 K, 600 lx ($M=4.9$, $SD= 2.0$) and 2700 K, 300 lx ($M=9.2$, $SD= 4.3$) conditions; $t(17)= -4.82$, $p= 0.000$; and the scores for 6500 K, 600 lx ($M=3.8$, $SD= 2.2$) and 2700 K, 300 lx ($M=9.2$, $SD= 4.3$) conditions; $t(17)= -5.92$, $p= 0.000$ (see Appendix C, table 15). Therefore, CCT have an effect on student’s error percentage in d2 test of attention at those conditions.

However, there was no significant difference in the scores for 6500 K, 300 lx ($M= 6.6$, $SD= 2.5$) and 2700 K, 600 lx ($M=5.5$, $SD= 3.1$) conditions; $t(17) = 1.821$, $p= 0.086$ (see Appendix C, Table 15). However, the mean of all conditions at 600 lx is lower than the conditions at 300 lx.

4.2.3.5 CP: Concentration performance

Conditions		N	Mean	STD	t	df	Sig
CP#1	6500 K, 300 Lx	18	189.778	31.9403	-6.535	17	0.000
	4600 K, 600 Lx	18	237.6	28.856			
CP#2	6500 K, 300 Lx	18	189.778	31.9403	-4.834	17	0.000
	2700 K, 600 Lx	18	230.66	38.662			
CP#3	6500 K, 600 Lx	18	238	31.293	5.752	17	0.000
	4600 K, 300 Lx	18	199.111	32.725			
CP#4	4600 K, 300 Lx	18	199.111	32.725	-3.114	17	0.006
	2700 K, 600 Lx	18	230.66	38.662			
CP#5	4600 K, 600 Lx	18	237.6	28.856	4.505	17	0.000
	2700 K, 300 Lx	18	198.5	38.14			
CP#6	6500 K, 600 Lx	18	238	31.293	6.794	17	0.000
	2700 K, 300 Lx	18	198.5	38.14			

Table 4.15: A table showing the “CP” mean values and the outcomes of t-test of (6500 K, 4600 K, and 2700 K CCT, 300 lx) at (6500 K, 4600 K, 2700 K CCT, 600 lx).

The t-test indicated that, the effect of CCT at 600 lx vs CCT at 300 lx on the “CP” was significant in the scores for 6500 K, 300 lx (M=190, SD=32) and 4600 K, 600 lx (M= 238, SD= 29) conditions; t (17) = -6.535, p= 0.000; and the scores for 6500 K, 300 lx (M=190, SD= 32) and 2700 K, 600 lx (M=231, SD= 39) conditions; t(17)= -4.834, p= 0.000; and the scores for 6500 K, 600 lx (M=238, SD= 31) and 4600 K, 300 lx (M=199, SD= 33) conditions; t(17)= 5.752, p= 0.000; and the scores for 4600 K, 300 lx (M= 199, SD= 33) and 2700 K, 600 lx (M=231, SD= 39) conditions; t(17)= -3.114, p= 0.006; and the scores for 4600 K, 600 lx (M=238, SD= 29) and 2700 K, 300 lx (M=198, SD= 38) conditions; t(17)= 4.505, p= 0.000; and the scores for 6500 K, 600 lx (M=238, SD= 31) and 2700 K, 300 lx (M=198, SD= 38) conditions; t(17)= 6.794, p= 0.000 (see Appendix C, table 16). Therefore, CCT have an effect on student's concentration performance in d2 test of attention at those conditions. The mean of all conditions at 600 lx are higher than the means at all conditions with 300 lx.

4.2.4 Analysis of the Similar CCT with different Lx

<u>4.2.4.1 TN: SPEED "number of items processed"</u>

Conditions		CCT	N	Mean	STD	t	df	Sig
TN#1	300 Lx	6500 K	18	521.278	70.445	-6.02	17	0.000
	600 Lx		18	585.55	64.3			
TN#2	300 Lx	4600 K	18	549.722	74.976	-6.01	17	0.000
	600 Lx		18	599.83	57.72			
TN#3	300 Lx	2700 K	18	568.055	76.925	-1.581	17	0.132
	600 Lx		18	593.44	68.47			

Table 4.16: A table showing the "TN" mean values and the outcomes of the t-test of (similar CCT at two different lx).

The t-test indicated that, the effect of the same CCT at two different lx on the "TN" was significant in the scores for 6500 K, 300 lx (M=521, SD=70) and 6500 K, 600 lx (M= 585, SD= 64) conditions; t (17) = -6.02, p= 0.000; and the scores for 4600 K, 300 lx (M=550, SD= 75) and 4600 K, 600 lx (M=600, SD= 58) conditions; t(17)= -6.01, p= 0.000 (see

Appendix C, table 17). Therefore, CCT have an effect on student's ability to scan the items in d2 test of attention at those conditions.

However, there was no significant difference in the scores for 2700 K, 300 lx (M= 568, SD= 77) and 2700 K, 600 lx (M=593, SD= 68) conditions; t (17) = -1.581, p= 0.132 (see Appendix C, table 17). The mean in all similar CCT conditions at 600 lx are higher than those at 300 lx.

4.2.4.2 EO: Error of Omission

Conditions		CCT	N	Mean	STD	t	df	Sig
EO#1	300 Lx	6500 K	18	34.2778	15.58	4.956	17	0.000
	600 Lx		18	22.055	14.139			
EO#2	300 Lx	4600 K	18	40.0556	17.965	4.737	17	0.000
	600 Lx		18	28.888	13.616			
EO#3	300 Lx	2700 K	18	51.166	27.53	5.871	17	0.000
	600 Lx		18	31.388	19.33			

Table 4.17: A table showing the "EO" mean values and the outcomes of the t-test of (similar CCT at two different lx).

The t-test indicated that, the effect of the same CCT at two different lx on the "EO" was significant in all three comparison; the scores for 6500 K, 300 lx (M=34, SD=15.6) and 6500 K, 600 lx (M= 22, SD= 14.1) conditions; t (17) = 4.956, p= 0.000; and the scores for 4600 K, 300 lx (M=40, SD= 18) and 4600 K, 600 lx (M=29, SD= 13.6) conditions; t(17)= 4.737, p= 0.000; and the scores for 2700 K, 300 lx (M=51, SD=27.5) and 2700 K, 600 lx (M=31.4, SD= 19.3) conditions; t(17)= 5.871, p= 0.000 (see Appendix C, table 18). Therefore, CCT have an effect on student's error of omission in d2 test of attention. The mean in all similar CCT conditions at 600 lx are lower than those at 300 lx.

4.2.4.3 EC: Error of Commission

Conditions		CCT	N	Mean	STD	t	df	Sig
EC#1	300 lx	6500 K	18	0.6667	0.84017	0.212	17	0.834
	600 lx		18	0.6111	0.6978			
EC#2	300 lx	4600 K	18	1.6111	2.4043	1.683	17	0.111
	600 lx		18	0.9444	1.1099			
EC#3	300 lx	2700 K	18	2.3889	1.61387	2.754	17	0.014
	600 lx		18	1.333	1.236			

Table 4.18: A table showing the "EC" mean values and the outcomes of the t-test of (similar CCT at two different lx).

The t-test indicated that, the effect of the same CCT at two different lx on the "EC" was significant in the scores for 2700 K, 300 lx (M=2.4, SD=1.6) and 2700 K, 600 lx (M= 1.3, SD= 1.2) conditions; t (17) = 2.754, p= 0.014 (see Appendix C, Table 19).

However, there was no significant difference in the scores for 6500 K, 300 lx (M= 0.67, SD= 0.84) and 6500 K, 600 lx (M=0.61, SD= 0.70) conditions; t (17) = 0.212, p= 0.834; and the scores for 4600 K, 300 lx (M=1.61, SD=2.4) and 4600 K, 600 lx (M= 0.94, SD= 1.1) conditions; t (17) = 1.683, p= 0.111 (see Appendix C, Table 19). Therefore, CCT have an effect on student's error of commission in d2 test of attention. The mean in all similar CCT conditions at 600 lx are lower than those at 300 lx.

<u>4.2.4.4 E%: Error Percentage</u>

Conditions		CCT	N	Mean	STD	t	df	Sig
E%#1	300 lx	6500 K	18	6.5667	2.4793	7.61	17	0.000
	600 lx		18	3.777	2.238			
E%#2	300 lx	4600 K	18	7.4389	2.8718	6.123	17	0.000
	600 lx		18	4.888	2.0395			
E%#3	300 lx	2700 K	18	9.2278	4.2846	6.906	17	0.000
	600 lx		18	5.5	3.114			

Table 4.19: A table showing the "E%" mean values and the outcomes of the t-test of (similar CCT at two different lx).

The t-test indicated that, the effect of the same CCT at two different lx on the "E%" was significant in all three comparison; the scores for 6500 K, 300 lx (M=6.6, SD=2.5) and 6500 K, 600 lx (M= 3.8, SD= 2.2) conditions; t (17) = 7.61, p= 0.000; and the scores for 4600 K, 300 lx (M=7.4, SD= 2.9) and 4600 K, 600 lx (M=4.9, SD= 2.0) conditions; t(17)= 6.123, p= 0.000; and the scores for 2700 K, 300 lx (M=9.2, SD=4.3) and 2700 K, 600 lx (M=5.5, SD=

3.1) conditions; t(17)= 6.906, p= 0.000 (see Appendix C, table 20). Therefore, CCT have an effect on student's error of omission in d2 test of attention. The mean in all similar CCT conditions at 600 lx are lower than those at 300 lx.

4.2.4.5 CP: Concentration performance

Conditions		CCT	N	Mean	STD	t	df	Sig
CP#1	300 lx	6500 K	18	189.778	31.9403	-10.294	17	0.000
	600 lx		18	238	31.293			
CP#2	300 lx	4600 K	18	199.111	32.725	-6.92	17	0.000
	600 lx		18	237.6	28.856			
CP#3	300 lx	2700 K	18	198.5	38.14	-4.373	17	0.000
	600 lx		18	230.66	38.662			

Table 4.20: A table showing the "CP" mean values and the outcomes of the t-test of (similar CCT at two different lx).

The t-test indicated that, the effect of the same CCT at two different lx on the "E%" was significant in all three comparison; the scores for 6500 K, 300 lx (M=190, SD=32) and 6500 K, 600 lx (M= 238, SD= 31.2) conditions; t (17) = -10.294, p= 0.000; and the scores for 4600 K, 300 lx (M=199, SD= 33) and 4600 K, 600 lx (M=238, SD= 29) conditions; t(17)= -6.92, p= 0.000; and the scores for 2700 K, 300 lx (M=198, SD=38) and 2700 K, 600 lx (M=231, SD= 39) conditions; t(17)= -4.373, p= 0.000 (see Appendix C, table 21). Therefore, CCT have an effect on student's concentration performance in d2 test of attention. The mean in all similar CCT conditions at 600 lx are higher than those at 300 lx.

4.3 Second Phase: Analysis of PANAS mood test

The effects of the CCT and lx that were used in the six conditions on student's mood were compared accordingly to the PANAS test as following:

1- Each condition measures the Positive affect (PA) before and after.
2- Each condition measures the Negative affect (NA) before and after.
3- These PA (before and after) and NA (before and after) were compared through the dependent t-test.

The highest point that can be reached is 50 points from PA/NA, and the lowest point that can be reached is 10 points from PA/NA. Getting the highest points from PA are the desired conditions and getting the lowest points from NA are the desired conditions (as cited in Rengin, 2015).

4.3.1 First Condition: 6500 K, 300 lx

Condition 6500 K 300 LUX	n	Mean	STD	t	df	Sig
Before PA	18	-0.277	6.841	-0.172	17	0.865
After PA						
Before NA	18	0.0555	5.115	0.046	17	0.964
After NA						

Table 4.21: A table showing the mood effect of the first condition through the mean values and the outcomes of the t-test of both PA and NA (before and after).

The t-test indicated that the results were not significant for both before PA and after PA results for the same condition; t (17) = -0.172, p= 0.865 (see Appendix C, Table 22). However, the mean values increased at the after PA, which is a desirable condition.

On the other hand, the t-test indicated that the results were not significant for both before NA and after NA results for the same condition; t (17) = 0.046, p= 0.964 (see Appendix C, Table 23). However, the mean value decreased at the after NA, which is a desirable condition.

4.3.2 Second Condition: 6500 K, 600 lx

Condition 6500 K 600 LUX	n	Mean	STD	t	df	Sig
Before PA	18	0.1667	5.227	0.135	17	0.894
After PA						
Before NA	18	-1.611	5.042	-1.356	17	0.193
After NA						

Table 4.22: A table showing the mood effect of the second condition through the mean values and the outcomes of the t-test of both PA and NA (before and after).

The t-test indicated that the results were not significant for both before PA and after PA results for the same condition; t (17) = 0.135, p= 0.894 (see Appendix C, Table 24). However, the mean values decreased at the after PA, which is not a desirable condition.

On the other hand, the t-test indicated that the results were not significant for both before NA and after NA results for the same condition; t (17) = -1.356, p= 0.193 (see Appendix C, Table 25). However, the mean value increased at the after NA, which is not a desirable condition.

4.3.3 Third Condition: 4600 K, 300 lx

Condition 4600 K 300 LUX	n	Mean	STD	t	df	Sig
Before PA	18	0.00	7.153	0.00	17	1
After PA						
Before NA	18	-2.444	5.893	-1.76	17	0.096
After NA						

Table 4.23: A table showing the mood effect of the third condition through the mean values and the outcomes of the t-test of both PA and NA (before and after).

The t-test indicated that the results were not significant for both before PA and after PA results for the same condition; t (17) = 0.000, p= 1 (see Appendix C, Table 26). However, the mean values did not change, which is not a desirable condition.

On the other hand, the t-test indicated that the results were not significant for both before NA and after NA results for the same condition; t (17) = -1.76, p= 0.096 (see Appendix C, Table 27). However, the mean values increased at the after NA, which is not a desirable condition.

4.3.4 Fourth Condition: 4600 K, 600 lx

Condition 4600 K 600 LUX	n	Mean	STD	t	df	Sig
Before PA	18	3	4.814	2.644	17	0.017
After PA						
Before NA	18	-1.5	2.706	-2.352	17	0.031
After NA						

Table 4.24: A table showing the mood effect of the fourth condition through the mean values and the outcomes of the t-test of both PA and NA (before and after).

The t-test indicated that the results were significant for both before PA and after PA results for the same condition; t (17) = 2.644, p= 0.017 (see Appendix C, Table 28). However, the mean values decreased at the after PA, which is not a desirable condition.

On the other hand, the t-test indicated that the results were significant for both before NA and after NA results for the same condition; t (17) = -2.352, p= 0.031 (see Appendix C, Table 29). However, the mean value increased at the after NA, which is not a desirable condition.

4.3.5 Fifth Condition: 2700 K, 300 lx

Condition 2700 K 300 LUX	n	Mean	STD	t	df	Sig
Before PA	18	1.833	6.363	1.222	17	0.238
After PA						
Before NA	18	-0.0555	8.585	-0.027	17	0.978
After NA						

Table 4.25: A table showing the mood effect of the fifth condition through the mean values and the outcomes of the t-test of both PA and NA (before and after).

The t-test indicated that the results were not significant for both before PA and after PA results for the same condition; t (17) = 1.222, p= 0.238 (see Appendix C, Table 30). However, the mean values decreased at the after PA, which is not a desirable condition.

On the other hand, the t-test indicated that the results were not significant for both before NA and after NA results for the same condition; t (17) = -0.027, p= 0.978 (see Appendix C, Table 31). However, the mean value increased at the after NA, which is not a desirable condition.

4.3.6 Sixth Condition: 2700 K, 600 lx

Condition 2700 K 600 LUX	n	Mean	STD	t	df	Sig
Before PA	18	1.111	5.028	0.938	17	0.362
After PA						
Before NA	18	-1.166	4.681	-1.057	17	0.305
After NA						

Table 4.26: A table showing the mood effect of the sixth condition through the mean values and the outcomes of the t-test of both PA and NA (before and after).

The t-test indicated that the results were not significant for both before PA and after PA results for the same condition; t (17) = 0.938, p= 0.362 (see Appendix C, Table 32). However, the mean values decreased at the after PA, which is not a desirable condition.

On the other hand, the t-test indicated that the results were not significant for both before NA and after NA results for the same condition; t (17) = -1.057, p= 0.305 (see Appendix C, Table 33). However, the mean value increased at the after NA, which is not a desirable condition.

4.4 Third Phase: Other Findings

4.4.1 Pearson correlation test between PANAS values and d2 test of attention values

The Pearson correlation test indicated that there was a positive correlation between delta PA and error of commission variables of the fourth condition; r= 0.517, n= 18, p=0.028 (see Appendix C, Table 37.). The findings agree with Knez (1995), who stated that there is a relationship between mood and sustained attention.

However, the Pearson correlation test indicated that there was no relationship between PANAS and d2 test of attention variables of the other conditions (See Appendix C, Table 34, 35, 36, 38, 39). Moreover, there was no relationship between the negative affect and d2 test of attention in all conditions (see Appendix C, Table 34-39). The findings disagree with what Knez proposed. However, the findings in those conditions agree with Rengin (2015), who did not find a relationship between mood and sustained attention.

CHAPTER 5

DISCUSSION

5.1 Discussion

This paper studied the effect of correlated color temperature and illuminance of university student’s mood and attention through all experiment conditions;

5.1.1 Similar illuminance (300 lx) with different CCT attention analyses.

In this thesis, it was found that there was no significant difference between (6500 K & 4600 K, 6500 K & 2700, 4600 K & 2700 K) on concentration performance (CP) at p=0.204,p=0.19 and p=0.947 respectively (see Appendix C, Table 6), total number of items processed (TN) between (4600 K and 2700 K, 6500K and 4600K) at p=0.331 and p=0.088 respectively (see Appendix C, Table 2), error of omission (EO) between 4600K and 2700 K at p=0.053 (see Appendix C, Table 3), and error of commission (EC) between (6500 K &

4600 K, 4600 K & 2700 K) at p= 0.132, and p=0.271 respectively (see Appendix C, Table 4).

On the other hand, it was found that there was a significant difference between (6500 K and 2700 K on the total number of items processed (TN) at p= 0.002 (See Appendix C, Table 2), error of omission (EO) between (6500K and 4600 K, 4600 K and 2700 K) at p=0.017 and p=0.005 respectively (see Appendix C, Table 3), error of commission (EC) between (6500 K and 2700 K) at p=0.003 (see Appendix C, Table 4), and number of errors (E%) between (6500 K and 4600K, 6500K and 2700 K, 4600 K and 2700 K) at p= 0.004, p=0.003, p=0.043 respectively (see Appendix C, Table 5).

This paper hypothesized that concentration performance is higher in 6500 K (daylight) than 4600 K and 2700 K at 300 lx. However, the findings of the different CCT at 300 lx indicated that there are no significant differences in concentration performance. Chellappa et al. (2011), stated that 6500 K results indicated faster reaction times in tasks associated with sustained attention; supported by Sleegers et al. (2012), who stated that 6500 K increases student concentration than 2900 K and 12000 K. Moreover, Yea et al. (2013), showed improved attention level at 6600 K compared with 4000 K. However, the result of these conditions contradicts with the above results and agrees with Vrabel et al (1998), who stated that there is no significant effect among (2700 K, 4100 K, 4200 K, and 5000 K) on visual performance.

Further, this paper hypothesized that E% is lowest at 6500 K and highest in 2700 K. The findings of the different CCT at 300 lx indicated that there are significant differences in the number of errors. The lowest mean of the number of errors (E%) is at 6500 K, and the highest is at 2700 K. According to Sleegers et al. (2012), who stated that 6500 K decrease student error; supported by Shamsul et al. (2013), who concluded that 4000 K and 6500 K are beneficial for alertness level and academic activities than 3000 K.

5.1.2 Similar illuminance (600 lx) with different CCT attention analyses.

In this thesis, it was found that there was no significant difference between (6500 K & 4600 K, 6500 K & 2700 K, 4600 K & 2700 K) on concentration performance (CP) at p=0.950,p=0.336 and p=0.408 respectively (see Appendix C, Table 11), total number of items processed (TN) between (6500 K and 4600 K, 6500 K and 2700 K, 4600 K and 2700 K) at p=0.208, p=0.607, p=0.677 respectively (see Appendix C, Table 7), error of omission (EO) between 4600K and 2700 K at p=0.535 (see Appendix C, Table 8), error of commission (EC) between (6500 K and 4600 K, 6500 K and 2700 K, 4600 K and 2700 K) at p= 0.302, p=0.055, and p=0.310 respectively (see Appendix C, Table 9), and number of errors (E%) between 4600 K and 2700 K at p=0.329 (see Appendix C, Table 10).

On the other hand, it was found that there was a significant difference between (6500 K and 2700 K on the error of omission (EO) between (6500K and 4600 K, 6500 K and 2700 K) at p=0.001 and p=0.031 respectively (see Appendix C, Table 8), number of errors (E%)

between (6500 K and 4600K, 6500K and 2700 K) at p= 0.001, p=0.012 respectively (see Appendix C, Table 10).

This paper hypothesized that concentration performance is higher in 6500 K (daylight) than 4600 K and 2700 K at 600 lx. However, the findings of the different CCT at 600 lx indicated that there are no significant differences in concentration performance. Chellappa et al. (2011), stated that 6500 K results indicated faster reaction times in tasks associated with sustained attention; supported by Sleegers et al. (2012), who stated that 6500 K increases student concentration than 2900 K and 12000 K. Moreover, Yea et al. (2013), showed improved attention level at 6600 K compared with 4000 K. However, the result of these conditions contradicts with the above results and agrees with Vrabel et al (1998), who stated that there is no significant effect among (2700 K, 4100 K, 4200 K, and 5000 K) on visual performance.

Further, this paper hypothesized that E% is lowest at 6500 K and highest in 2700 K. The findings of the different CCT at 600 Lx indicated that there are significant differences in the number of errors. The lowest mean of the number of errors (E%) is at 6500 K, and the highest is at 2700 K. According to Sleegers et al. (2012), who stated that 6500 K decrease student error; supported by Shamsul et al. (2013), who concluded that 4000 K and 6500 K are beneficial for alertness level and academic activities than 3000 K.

5.1.3 Different illuminance with different CCT attention analyses.

In this thesis, it was found that there was a significant difference between the six comparison on concentration performance (CP) at $p < 0.05$ (see Appendix C, Table 16), total number of items processed (TN) between (6500 K/300lx & 4600 K/600lx, 6500 K/300 lx & 2700 K/600 lx, 6500K/600 lx & 4600 K/300 lx, 4600 K/300lx & 2700 K/600lx) at p=0.000, p= 0.000, 0.010 and p=0.037 respectively (see Appendix C, Table 12), error of omission (EO) between (6500 K/300lx & 4600 K/600lx, 6500 K/600lx & 4600 K/300lx, 4600 K/300 & 2700 K/600lx, 4600 K/600lx & 2700 K/300lx, 6500 K/600lx & 2700 K/300lx) at p=0.040, p=0.000, p=0.049, p=0.002, and p=0.000 respectively (see Appendix C, Table 13), error of commission (EC) between (4600 K/600lx & 2700 K/300lx, 6500 K/600lx & 2700 K/300lx) at p= 0.005, and p=0.000 respectively (see Appendix C, Table 14), and the number of errors (E%) between (6500 K/300lx & 4600 K/600lx, 6500 K/600lx & 4600 K/300lx, 4600 K/300lx & 2700 K/600lx, 4600 K/600lx & 2700 K/300lx, 6500 K/600lx & 2700 K/300lx) at p= 0.000, p=0.000, p=0.007, p=0.000, and p=0.000 respectively (see Appendix C, Table 15)

On the other hand, it was found that there was no significant difference between (4600 K/600lx & 2700 K/300lx, 6500 K/600lx & 2700 K/300lx) on the total number of items processed (TN) at p= 0.071 and p= 0.0241 (See Appendix C, Table 12), error of omission (EO) between (6500 K/300lx & 2700 K/600lx) at p=0.482 (see Appendix C, Table 13), error of commission (EC) between (6500 K/300lx & 4600 K/600lx, 6500 K/600lx & 4600

K/300lx, 4600 K/300lx & 2700 K/600lx) at p=0.439, p=0.104, p=0.672 (see Appendix C, Table 14), and number of errors (E%) between (6500 K/300lx & 2700 K/600lx) at p= 0.086 (see Appendix C, Table 15).

This paper hypothesized that concentration performance is higher in 6500 K (daylight) at 600 lx than other conditions. The findings of these conditions indicated that there are significant differences in concentration performance. Higher illuminance at different CCT indicated higher mean (concentration performance) than all CCT condition at the lower illuminance. The highest mean is at 6500 K/ 600 lx, and the lowest is at 6500 K/ 300 lx. According to Zhu et al. (2017), who concluded that participants performed better in the "bright" lighting condition than "dim" lighting conditions. Moreover, Yea et al. (2013), conduct an experiment that showed 6600 K at 800 lx improved attention level compared with 4000 K at 500 lx.

The result also indicated that there are significant differences in the number of errors. Higher illuminance at different CCT indicated lower mean (less mistake) than all different CCT at the lower illuminance. The higher number of errors was at 2700 K at 300 lx, and the lowest number of errors was at 6500 K at 600 lx. According to Viola et al. (2008), stated that exposure to 17000 K than 4000 K improves subjective alertness, performance, and evening fatigue; supported by Navvab (2001), who showed that 6500 K is better than 3500 K in terms of visual performance.

5.1.4 Similar CCT with different illuminance attention analyses.

In this thesis, it was found that there was no significant difference between (2700 K/300lx & 2700 K/600 lx) on the total number of items processed (TN) at p=0.132 (see Appendix C, Table 17), error of commission (EC) between (6500 K/300lx & 6500 K/600lx, 4600 K/300lx & 4600 K/600lx) at p= 0.834, p=0.111, and p=0.310 respectively (see Appendix C, Table 19).

On the other hand, it was found that there was a significant difference between (6500 K/ 300lx & 6500 K/600lx, 4600 K/300lx & 4600K/600lx, 2700 K/300lx & 2700 K/600lx) on the concentration performance (CP) all at p=0.000 (see Appendix C, Table 21), error of commission (EC) between (2700 K/300lx & 2700 K/600lx) at p=0.014 (see Appendix C, Table 19), error of omission (OE) between (all three conditions) at p=0.000 (see Appendix C, Table 18), number of errors (E%) between (all three conditions) at p= 0.000 (see Appendix C, Table 20), total number of items processed (TN) between (6500 K/300lx & 6500 K/600lx, 4600K/300lx, 4600K/600lx) at p=0.000 (see Appendix C, Table 17).

The findings of these conditions indicated that there are significant differences in concentration performance. Higher illuminance at similar CCT indicated higher mean (concentration performance) than the lower illuminance at similar CCT. The highest mean is at 6500 K at 600 lx, and the lowest is at 6500 K at 300 lx (see Appendix D, Figure 1-2)

The result also indicated that there are significant differences in the number of errors. Higher illuminance at similar CCT indicated lower mean (less mistake) than the lower illuminance at similar CCT. The higher number of errors was at 2700 K at 300lx, and the lowest number of errors was at 6500 K at 600lx (see Appendix D, Figure 3-5). The results of these conditions are similar to Navvab (2001), Yea et al. (2013), Chellappa et at (2011), Sleeger et al. (2012), Zhu et al. (2017), Viola et al. (2008), and Huang et al. (2014).

5.1.5 PANAS Analyses of all six conditions

The result of (4600 K, 600 lx) conditions indicated a significant difference between (PA before & PA after, NA before & NA after) at p=0.017 and p=0.031 (see Appendix C, Table 31, 32). The findings of this condition indicated that this condition has an influence on student mood. However, both positive and negative mood increased significantly, which is not a desirable situation. Moreover, all other conditions did not indicate any significant results in student mood (see Appendix C, Table 22,23,24,25,26,27,30,31,32,33).

Participants are more pleasant with higher CCT levels of lighting (Boyce, 2004). Zhu et al. (2017), demonstrated that participants felt less sleepy "positive mood" in bright then dim lighting conditions; supported by Pulay et al. (2018), who concluded that students under 4100 K display more on-task behaviors than 3000 K. Moreover, Chellappa et al (2011), stated that 6500 K induced more melatonin suppression, with enhanced subject alertness than 3000 K and 2500 K. Kuller et al. (2006), presented that light and color of workplace has an influence on the mood and mood was lowest when the subject experienced the too dark condition and increased when it was “right” and then declined again when it was too bright. However, other studies found that lower CCT is more pleasant than higher CCT (Smolders et al., 2017; Baron et al., 1992).

It was hypothesized that a positive mood would be highest at 6500 K at 600 lx. However, this study could not conclude if different CCT & illuminance has an influence on student mood (see Appendix D, figure 6-11).

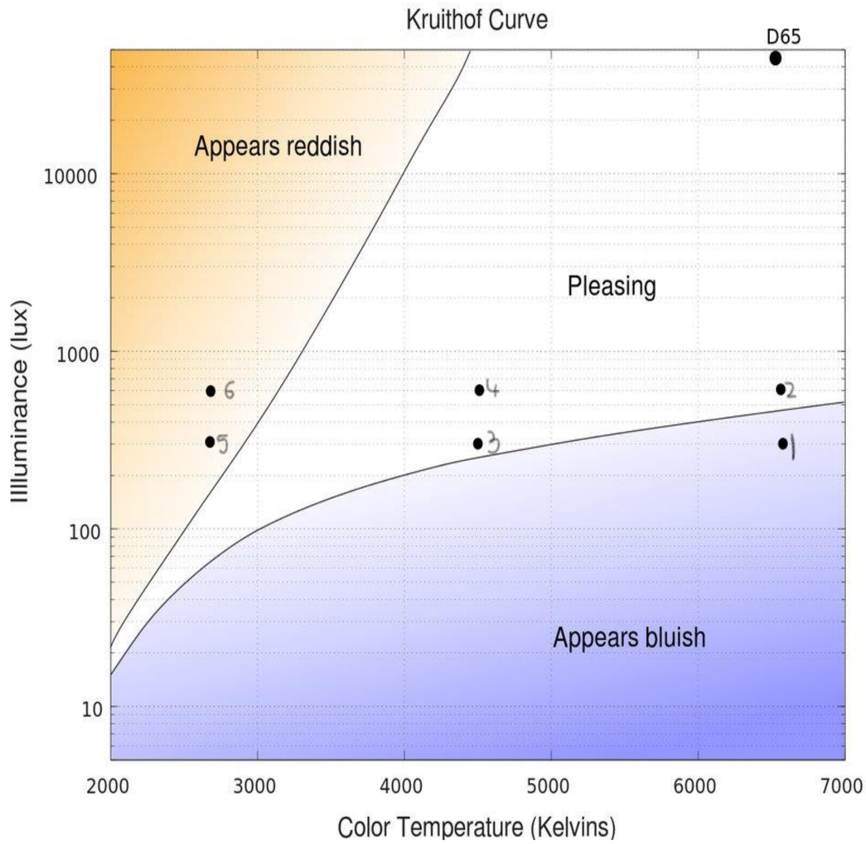
5.1.6 Pearson Correlation test between PANAS values and d2 test values.

The findings of the Pearson correlation test indicated that there was a positive correlation between delta PA and error of commission variables of the fourth condition only (4600 K, 600 lx) (see Appendix C, Table 37; see Appendix D, Figure 32). Thus, it agrees with Knez (1995), who stated that there is a relationship between mood and sustained attention.

However, the findings of the other conditions including the (delta NA) disagree with what Knez proposed and agree with Rengin (2015), who did not find a relationship between mood and sustained attention in his experiment (see Appendix C, Table 34-39; see Appendix D, Figure 12-47). Thus, this thesis could not conclude that there is a relationship between PANAS and d2 test values.

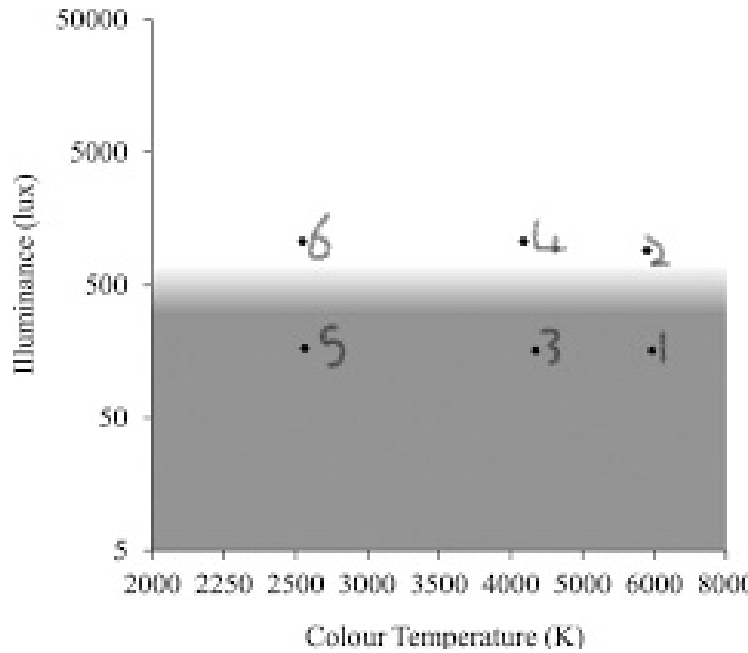
5.2 Overall Discussion.

The results indicated that higher illuminance is better for the educational environment. The findings of higher illuminance comparing with lower illuminance indicated less mistake and participants are more concentrated. Further, Fotios (2017) contributed a revised Kruithof graph that demonstrated the pleasant and unpleasant conditions of the illuminance. In addition, the author concluded that the variation in CCT (2500 K to 6500 K) does not affect the pleasant conditions and it depends on illuminance. Thus, the result of the six conditions of this research paper are plotted in the initial Kruithof curve (Figure 5.1) and the revised Kruithof curve (Figure 5.2). The result of this study indicated higher concentration performance and lower error percentage at higher illuminance. Thus, the result of this paper asserts that higher illuminance is more pleasant. However, the initial Kruithof curve indicated that the sixth condition (2700 K, 600 lx) to be unpleasant, whereas the third condition (4600 K, 300 lx) is considered pleasant. However, the findings of this paper contradict the initial Kruithof curve in these two conditions. On the other hand, the revised Kruithof curve indicated that higher illuminance (500 lx and above) are pleasant. The findings of this paper agree with the revised Kruithof curve. Further, this paper recommends 6500 K at 600 lx conditions in classrooms, especially during exams.



Condition
1= 6500 K, 300 lx
2= 6500 K, 600 lx
3= 4600 K, 300 lx
4= 4600 K, 600 lx
5= 2700 K, 300 lx
6= 2700 K, 600 lx

Figure 5.1: All conditions of this paper experiment are plotted in the initial Kruithof curve.



Condition
1= 6500 K, 300 lx
2= 6500 K, 600 lx
3= 4600 K, 300 lx
4= 4600 K, 600 lx
5= 2700 K, 300 lx
6= 2700 K, 600 lx

Figure 5.2: The revised Kruithof curve with the conditions of this research experiment.

CHAPTER 6

6.1 Conclusion

This paper investigated the effects of CCT and lx on undergraduate student attention and mood through six conditions. The study tested seven hypotheses.

The first hypotheses assumed that concentration performance would be higher in (6500 K, 300 lx) comparted to (4600 K, 300 lx) and (2700 K, 300lx). The findings revealed that there are no significant differences in concentration performance. However, the mean of 6500 K, 300 lx was lowest than 4600 K, 300 lx, and 2700 K, 300 lx.

The second hypothesis assumed that E% is lowest at 6500 K compared to 4600 K and 2700 K at 300 lx. The findings assert that E% is lowest at 6500 K at the other conditions at 300 lx.

The third hypothesis assumed that concentration performance is higher at 6500 K, 600 lx than other CCT conditions at 600 lx. The findings indicated no significant differences in concentration performance. However, the mean of 6500 K, 600 lx had the highest concentration performance result.

The fourth hypothesis assumed that E% decreased at 6500 K compared to all conditions at 600 lx. The findings revealed that 6500 K is lower than 4600 K and 2700 K at 600 lx in terms of E%.

The fifth hypothesis assumed that concentration performance is higher in 6500 K, 600 lx than all other conditions. The findings indicated that there are significant differences in concentration performance. Higher illuminance at different CCT had higher CP compared to CCT at lower illuminance. The 6500 K, 600 lx condition had the highest mean compared with all other conditions.

The sixth hypothesis assumed that E% is lowest at 6500 K, 600 lx than all other conditions. The result of this study indicated that E% is lower at higher illuminance than lower illuminance with similar CCT. The lowest E% mean is at 6500 K, 600 lx.

The seventh hypothesis assumed that the student's positive affect increased at 6500 K, 600 lx. The result of this paper indicated significant differences at 4600 K, 600 lx but did not indicate any significant differences at the other conditions. Thus, the result contradicts the seventh hypothesis.

However, the findings of this research could not conclude whether mood or attention are affected by the proposed conditions due to several limitation in this paper;

1- The group sample was too small (n=18), with unequal female/male ratio (87.5% female).
2- The timeline of the experiment was short due to the class schedule.
3- Additional survey's that includes student preference/activity could not be handed that would benefit the analysis of this study due to timing.
4- New lighting fixture type (LED) could not be used due to timing and cost of installing new lighting system in the classroom. Thus, similar lighting fixture type (Fluorescent lamp) was used.

6.2 Recommendation

Moreover, this paper sets some recommendations based on the result of the paper analysis. The results indicated that higher illuminance is suitable for academic activities and tests. In addition, 6500 K, 600 lx condition indicated highest result in concentration performance and lowest in terms of error percentage. Thus, this paper recommends to design classrooms in a way that benefits from natural daylight and high illuminance. However, if it is not possible to benefit from daylight then artificial daylight color temperature (6500 K) with high illuminance could be proposed in classrooms.

This paper set some recommendation for future studies that are interested in the effect of CCT and lx on student attention and mood;

1- Future studies could use more than one classroom and increase the duration of the experiment in order to assess the mood and attention of students through long sessions.
2- Age and gender are important factors in experimenting the effects of CCT and lx on participants. One of the limitations of this study was the unequal ratio of male and female students in the department of architecture of Kuwait University.
3- Future studies should use new technology in lighting (LED lighting) which have a better S/P ratio that decrease the watts and increase the efficiency to contribute more to this field.

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APPENDIX A

***Figure A1*:** "Eye and the principal components of the brain that comprise the visual system" (Source: Dilaura, 2011)

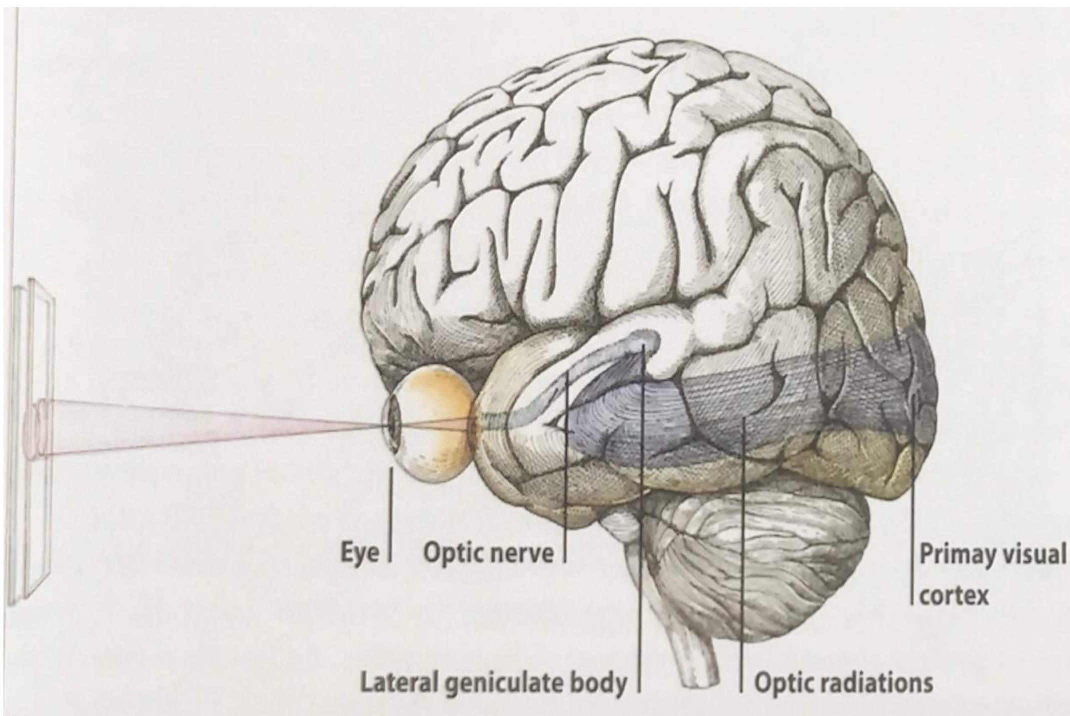

***Figure A2*:** "Melatonin phase shift and suppression" (Source: Dilaura, 2011)

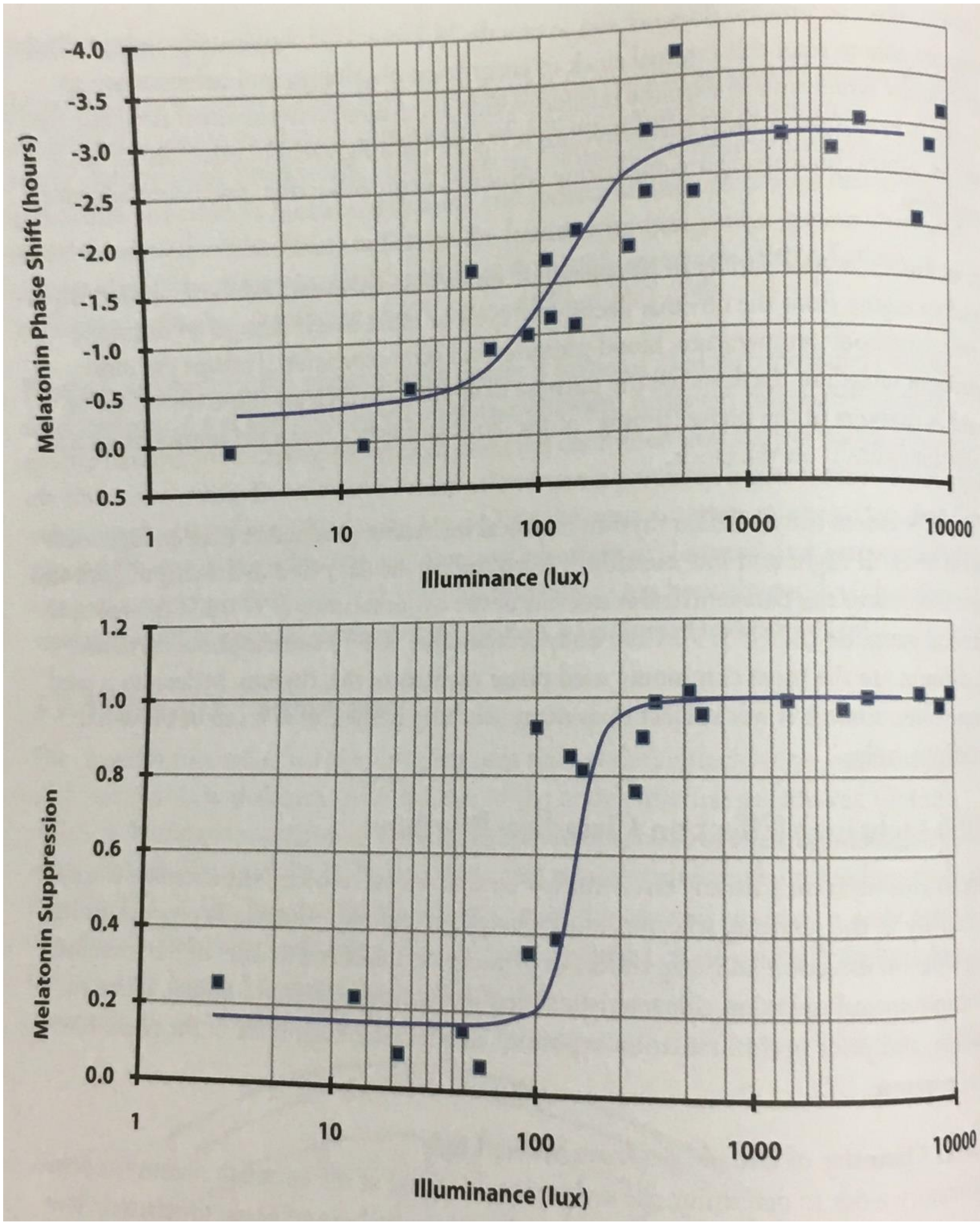

***Figure A3*:** The PANAS-D (Arabic version) (Source: Mnadla et al., 2017)

مدى تردد ما أشعر به							التأثير المتوقع لهذه الشدّة على الأداء							شدة ما أشعر به				
دائما	في كثير من الأحيان	غالبا	بصفة منتظمة	أحيانا	نادرا	على الاطلاق	مناسبة جدا	مناسبة بشكل متوسط	مناسبة إلى حدّ ما	لا تأثير لها على الأداء	غير ملائمة إلى حدّ ما	غير ملائمة بشكل متوسط	غير ملائمة جدا	بشدة	إلى حدّ ما	ضعيفا	على الاطلاق	
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	1. مهتم (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	2. قلق (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	3. منفعل (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	4. غاضب (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	5. قويّ (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	6. مذنب (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	7. خائف (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	8. عدائي (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	9. متحمّس (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	10.فخور (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	11.منزعج (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	12.حذر (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	13.خجول (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	14.ملهم (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	15.متوتر (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	16.مصرّ (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	17.منتبه (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	18.مضطرب (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	19.نشيط (ة)
7	6	5	4	3	2	1	3	2	1	0	-1	-2	-3	4	3	2	1	20.جبان (ة)

APPENDIX B

Table B1**:** Shows the NCS code of the classroom

	Color	**NCS CODE**	**Blackness**	**Chromaticness**
WALL (PAINT)		S 0502-Y	05	02
CEILING (PAINT)		S 0502-N	05	02
CURTAIN		S 6020-R90B	60	20
WALL LEFT SIDE (PAINT)		S 1005-R70B	10	05
DOOR (PAINT)		S 7020-Y50R	70	20
FLOOR (CARPET)		S 1010-Y10R	10	10
CHAIR		S 9000- N	90	00

DESK		S 2030-Y10R	20	30
LARGE SCREEN		S 9000- N	90	00

***Table B2*:** Shows the Reflectance of surface % in the classroom

Location	**Reflectance of Surface %**
Front Wall	57.90%
Back Wall	57.80%
Left Wall	49.10%
Right Wall	58.10%
Curtain (on Left Wall)	15.70%

***Figure B1*:** Shows the total luminaire fixtures in the classroom (Blue: existing luminaire. Red new luminaire to reach the 600 lx).

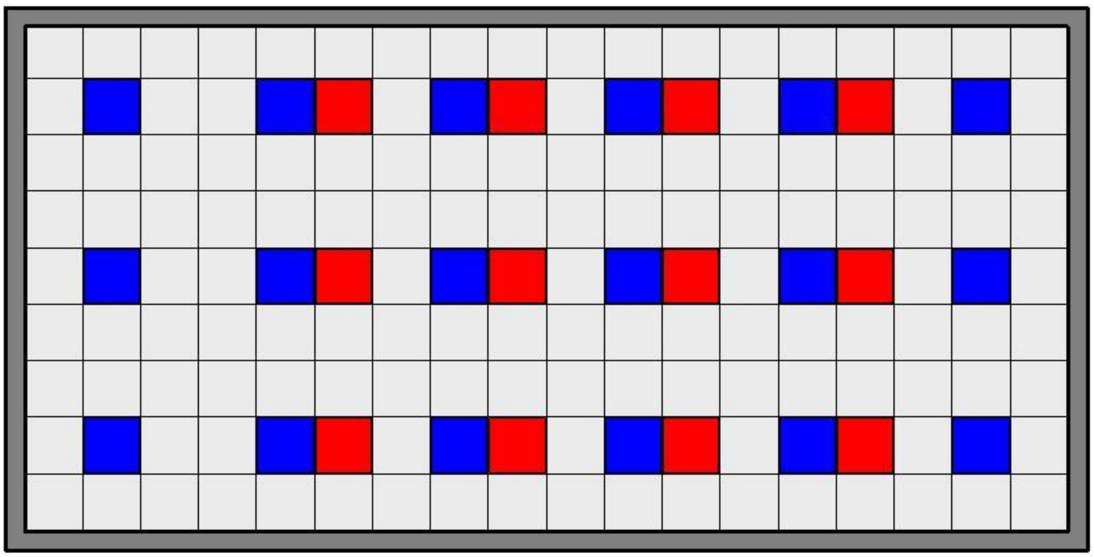

***Figure B2*:** The picture of the lighting meter that was used in the experiment "Testo-545".

Table B3**:** Shows the illuminance measure of the first and second and the final average of each condition.

Illuminance Measure					
Condition	**Location Seat**	**Readings**	**Condition**	**Location Seat**	**Readings**
1	**2**	**295**	**2**	**2**	**608**
1	**6**	**320**	**2**	**6**	**630**
1	**10**	**311**	**2**	**10**	**624**
1	**14**	**309**	**2**	**14**	**618**
1	**15**	**307**	**2**	**15**	**607**
1	**18**	**305**	**2**	**18**	**611**
1	**23**	**310**	**2**	**23**	**618**
1	**27**	**298**	**2**	**27**	**602**
1	**31**	**307**	**2**	**31**	**611**
1	**33**	**293**	**2**	**33**	**604**
1	**37**	**286**	**2**	**37**	**603**
1	**42**	**309**	**2**	**42**	**617**
1	**43**	**317**	**2**	**43**	**620**
1	**48**	**296**	**2**	**48**	**604**
AVG		**305**	**AVG**		**613**

***Table B4*:** Shows the illuminance measure of the third and fourth conditions and the final average of each condition.

Illuminance Measure					
Condition	**Location Seat**	**Readings**	**Condition**	**Location Seat**	**Readings**
3	**2**	**289**	**4**	**2**	**597**
3	**6**	**312**	**4**	**6**	**621**
3	**10**	**307**	**4**	**10**	**615**
3	**14**	**301**	**4**	**14**	**603**
3	**15**	**299**	**4**	**15**	**598**
3	**18**	**297**	**4**	**18**	**602**
3	**23**	**301**	**4**	**23**	**605**
3	**27**	**290**	**4**	**27**	**594**
3	**31**	**297**	**4**	**31**	**601**
3	**33**	**293**	**4**	**33**	**596**
3	**37**	**287**	**4**	**37**	**598**
3	**42**	**301**	**4**	**42**	**617**
3	**43**	**305**	**4**	**43**	**623**
3	**48**	**297**	**4**	**48**	**598**
AVG		**298**	**AVG**		**605**

***Table B5*:** Shows the illuminance measure of the fifth and sixth conditions and the final average of each condition.

Illuminance Measure					
Condition	**Location Seat**	**Readings**	**Condition**	**Location Seat**	**Readings**
5	**2**	**287**	**6**	**2**	**600**
5	**6**	**314**	**6**	**6**	**629**
5	**10**	**305**	**6**	**10**	**621**
5	**14**	**302**	**6**	**14**	**607**
5	**15**	**297**	**6**	**15**	**593**
5	**18**	**296**	**6**	**18**	**598**
5	**23**	**303**	**6**	**23**	**608**
5	**27**	**289**	**6**	**27**	**603**
5	**31**	**286**	**6**	**31**	**610**
5	**33**	**290**	**6**	**33**	**595**
5	**37**	**297**	**6**	**37**	**601**
5	**42**	**304**	**6**	**42**	**621**
5	**43**	**309**	**6**	**43**	**626**
5	**48**	**301**	**6**	**48**	**609**
AVG		**299**	**AVG**		**609**

APPENDIX C

***Table C1*:** Shows the ANOVA results of the d2 test of attention for all conditions.

Multivariate Tests[a]

Effect			Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Between Subjects	Intercept	Pillai's Trace	.999	2799.49[b]	5.000	13.000	.000	.999
		Wilks' Lambda	.001	2799.49[b]	5.000	13.000	.000	.999
		Hotelling's Trace	1076.729	2799.49[b]	5.000	13.000	.000	.999
		Roy's Largest Root	1076.729	2799.49[b]	5.000	13.000	.000	.999
Within Subjects	Conditions	Pillai's Trace	.[c]	.	.	.	.	.
		Wilks' Lambda	.[c]	.	.	.	.	.
		Hotelling's Trace	.[c]	.	.	.	.	.
		Roy's Largest Root	.[c]	.	.	.	.	.

***Table C2*:** Shows the "TN" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 300 lx.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 2	TN: 6500 K, 300 LUX - TN: 4600 K, 300 LUX	-28.44444	66.75788	15.73498	-61.64236	4.75347	-1.808	17	.088
Pair 4	TN: 6500 K, 300 LUX - TN: 2700 K, 300 LUX	-46.77778	53.82166	12.68589	-73.54266	-20.01290	-3.687	17	.002
Pair 11	TN: 4600 K, 300 LUX - TN: 2700 K, 300 LUX	-18.33333	77.75376	18.32674	-56.99937	20.33270	-1.000	17	.331

***Table C3*:** Shows the "EO" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 300 lx.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 2	EO: 6500 K, 300 LUX - EO: 4600 K, 300 LUX	-5.77778	9.28981	2.18963	-10.39749	-1.15806	-2.639	17	.017
Pair 4	EO: 6500 K, 300 LUX - EO: 2700 K, 300 LUX	-16.88889	22.31562	5.25984	-27.98619	-5.79159	-3.211	17	.005
Pair 11	EO: 4600 K, 300 LUX - EO: 2700 K, 300 LUX	-11.11111	22.61933	5.33143	-22.35944	.13722	-2.084	17	.053

Table C4: Shows the "EC" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 300 lx.

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 2	EC: 6500 K, 300 LUX - EC: 4600 K, 300 LUX	-.94444	2.53150	.59668	-2.20333	.31444	-1.583	17	.132
Pair 4	EC: 6500 K, 300 LUX - EC: 2700 K, 300 LUX	-1.72222	2.10896	.49709	-2.77098	-.67346	-3.465	17	.003
Pair 11	EC: 4600 K, 300 LUX - EC: 2700 K, 300 LUX	-.77778	2.90143	.68387	-2.22063	.66507	-1.137	17	.271

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***Table C5*:** Shows the "E%" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 300 lx.

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 2	E%: 6500 K, 300 LUX - E%: 4600 K, 300 LUX	-.87222	1.11133	.26194	-1.42488	-.31957	-3.330	17	.004
Pair 4	E%: 6500 K, 300 LUX - E%: 2700 K, 300 LUX	-2.66111	3.32002	.78254	-4.31212	-1.01011	-3.401	17	.003
Pair 11	E%: 4600 K, 300 LUX - E%: 2700 K, 300 LUX	-1.78889	3.46306	.81625	-3.51103	-.06675	-2.192	17	.043

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***Table C6*:** Shows the “CP” mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 300 lx.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 2	CP: 6500 K, 300 LUX - CP: 4600 K, 300 LUX	-9.33333	29.99804	7.07061	-24.25101	5.58434	-1.320	17	.204
Pair 4	CP: 6500 K, 300 LUX - CP: 2700 K, 300 LUX	-8.72222	27.08984	6.38514	-22.19368	4.74924	-1.366	17	.190
Pair 11	CP: 4600 K, 300 LUX - CP: 2700 K, 300 LUX	.61111	38.13465	8.98842	-18.35280	19.57503	.068	17	.947

***Table C7*:** Shows the “TN” mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 600 lx.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 7	TN: 6500 K, 600 LUX - TN: 4600 K, 600 LUX	-14.27778	46.31580	10.91674	-37.31008	8.75453	-1.308	17	.208
Pair 9	TN: 6500 K, 600 LUX - TN: 2700 K, 600 LUX	-7.88889	63.91528	15.06498	-39.67321	23.89543	-.524	17	.607
Pair 14	TN: 4600 K, 600 LUX - TN: 2700 K, 600 LUX	6.38889	63.95048	15.07327	-25.41293	38.19071	.424	17	.677

***Table C8*: ** Shows the “EO” mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 600 lx.

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 7	EO: 6500 K, 600 LUX - EO: 4600 K, 600 LUX	-6.83333	7.37444	1.73817	-10.50056	-3.16611	-3.931	17	.001
Pair 9	EO: 6500 K, 600 LUX - EO: 2700 K, 600 LUX	-9.33333	16.88717	3.98034	-17.73112	-.93554	-2.345	17	.031
Pair 14	EO: 4600 K, 600 LUX - EO: 2700 K, 600 LUX	-2.50000	16.75867	3.95006	-10.83389	5.83389	-.633	17	.535

***Table C9*: ** Shows the “EC” mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 600 lx.

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 7	EC: 6500 K, 600 LUX - EC: 4600 K, 600 LUX	-.33333	1.32842	.31311	-.99394	.32728	-1.065	17	.302
Pair 9	EC: 6500 K, 600 LUX - EC: 2700 K, 600 LUX	-.72222	1.48742	.35059	-1.46190	.01745	-2.060	17	.055
Pair 14	EC: 4600 K, 600 LUX - EC: 2700 K, 600 LUX	-.38889	1.57700	.37170	-1.17311	.39533	-1.046	17	.310

***Table C10*:** Shows the “E%” mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 600 lx.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 7	E%: 6500 K, 600 LUX - E%: 4600 K, 600 LUX	-1.11111	1.18217	.27864	-1.69899	-.52323	-3.988	17	.001
Pair 9	E%: 6500 K, 600 LUX - E%: 2700 K, 600 LUX	-1.72222	2.58219	.60863	-3.00632	-.43813	-2.830	17	.012
Pair 14	E%: 4600 K, 600 LUX - E%: 2700 K, 600 LUX	-.61111	2.58022	.60816	-1.89422	.67200	-1.005	17	.329

***Table C11*:** Shows the “CP” mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT) at 600 lx.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 7	CP: 6500 K, 600 LUX - CP: 4600 K, 600 LUX	.38889	26.08389	6.14803	-12.58232	13.36010	.063	17	.950
Pair 9	CP: 6500 K, 600 LUX - CP: 2700 K, 600 LUX	7.33333	31.43434	7.40914	-8.29860	22.96526	.990	17	.336
Pair 14	CP: 4600 K, 600 LUX - CP: 2700 K, 600 LUX	6.94444	34.69272	8.17715	-10.30784	24.19673	.849	17	.408

***Table C12*:** Shows the "TN" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT, 300 lx) at (6500 K, 4600 K, 2700 K CCT, 600 lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 3	TN: 6500 K, 300 LUX - TN: 4600 K, 600 LUX	-78.55556	56.31239	13.27296	-106.55905	-50.55206	-5.918	17	.000
Pair 5	TN: 6500 K, 300 LUX - TN: 2700 K, 600 LUX	-72.16667	63.72667	15.02052	-103.85719	-40.47614	-4.805	17	.000
Pair 6	TN: 6500 K, 600 LUX - TN: 4600 K, 300 LUX	35.83333	52.15728	12.29359	9.89613	61.77054	2.915	17	.010
Pair 8	TN: 6500 K, 600 LUX - TN: 2700 K, 300 LUX	17.50000	61.07686	14.39595	-12.87281	47.87281	1.216	17	.241
Pair 12	TN: 4600 K, 300 LUX - TN: 2700 K, 600 LUX	-43.72222	82.11026	19.35357	-84.55469	-2.88975	-2.259	17	.037
Pair 13	TN: 4600 K, 600 LUX - TN: 2700 K, 300 LUX	31.77778	69.90040	16.47568	-2.98287	66.53843	1.929	17	.071

***Table C13*:** Shows the "EO" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT, 300 lx) at (6500 K, 4600 K, 2700 K CCT, 600 lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 3	EO: 6500 K, 300 LUX - EO: 4600 K, 600 LUX	5.38889	10.25635	2.41745	.28852	10.48925	2.229	17	.040
Pair 5	EO: 6500 K, 300 LUX - EO: 2700 K, 600 LUX	2.88889	17.03246	4.01459	-5.58115	11.35893	.720	17	.482
Pair 6	EO: 6500 K, 600 LUX - EO: 4600 K, 300 LUX	-18.00000	12.02938	2.83535	-23.98207	-12.01793	-6.348	17	.000
Pair 8	EO: 6500 K, 600 LUX - EO: 2700 K, 300 LUX	-29.11111	25.60076	6.03416	-41.84207	-16.38015	-4.824	17	.000
Pair 12	EO: 4600 K, 300 LUX - EO: 2700 K, 600 LUX	8.66667	17.30012	4.07768	.06352	17.26981	2.125	17	.049
Pair 13	EO: 4600 K, 600 LUX - EO: 2700 K, 300 LUX	-22.27778	24.29429	5.72622	-34.35904	-10.19651	-3.890	17	.001

***Table C14*:** Shows the "EC" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT, 300 lx) at (6500 K, 4600 K, 2700 K CCT, 600 lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 3	EC: 6500 K, 300 LUX - EC: 4600 K, 600 LUX	-.27778	1.48742	.35059	-1.01745	.46190	-.792	17	.439
Pair 5	EC: 6500 K, 300 LUX - EC: 2700 K, 600 LUX	-.66667	1.57181	.37048	-1.44831	.11498	-1.799	17	.090
Pair 6	EC: 6500 K, 600 LUX - EC: 4600 K, 300 LUX	-1.00000	2.47339	.58298	-2.22999	.22999	-1.715	17	.104
Pair 8	EC: 6500 K, 600 LUX - EC: 2700 K, 300 LUX	-1.77778	1.55509	.36654	-2.55111	-1.00445	-4.850	17	.000
Pair 12	EC: 4600 K, 300 LUX - EC: 2700 K, 600 LUX	.27778	2.73981	.64578	-1.08470	1.64025	.430	17	.672
Pair 13	EC: 4600 K, 600 LUX - EC: 2700 K, 300 LUX	-1.44444	1.88562	.44444	-2.38214	-.50675	-3.250	17	.005

***Table C15*:** Shows the "E%" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT, 300 lx) at (6500 K, 4600 K, 2700 K CCT, 600 lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 3	E%: 6500 K, 300 LUX - E%: 4600 K, 600 LUX	1.67778	1.56339	.36849	.90032	2.45523	4.553	17	.000
Pair 5	E%: 6500 K, 300 LUX - E%: 2700 K, 600 LUX	1.06667	2.48572	.58589	-.16945	2.30279	1.821	17	.086
Pair 6	E%: 6500 K, 600 LUX - E%: 4600 K, 300 LUX	-3.66111	2.08415	.49124	-4.69754	-2.62469	-7.453	17	.000
Pair 8	E%: 6500 K, 600 LUX - E%: 2700 K, 300 LUX	-5.45000	3.90750	.92101	-7.39315	-3.50685	-5.917	17	.000
Pair 12	E%: 4600 K, 300 LUX - E%: 2700 K, 600 LUX	1.93889	2.70775	.63822	.59235	3.28542	3.038	17	.007
Pair 13	E%: 4600 K, 600 LUX - E%: 2700 K, 300 LUX	-4.33889	3.81485	.89917	-6.23597	-2.44181	-4.825	17	.000

***Table C16*:** Shows the "CP" mean values and the outcomes of the t-test of (6500 K, 4600 K, and 2700 K CCT, 300 lx) at (6500 K, 4600 K, 2700 K CCT, 600 lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 3	CP: 6500 K, 300 LUX - CP: 4600 K, 600 LUX	-47.83333	31.05261	7.31917	-63.27543	-32.39123	-6.535	17	.000
Pair 5	CP: 6500 K, 300 LUX - CP: 2700 K, 600 LUX	-40.88889	35.88690	8.45862	-58.73502	-23.04276	-4.834	17	.000
Pair 6	CP: 6500 K, 600 LUX - CP: 4600 K, 300 LUX	38.88889	28.68262	6.76056	24.62536	53.15242	5.752	17	.000
Pair 8	CP: 6500 K, 600 LUX - CP: 2700 K, 300 LUX	39.50000	24.66541	5.81369	27.23418	51.76582	6.794	17	.000
Pair 12	CP: 4600 K, 300 LUX - CP: 2700 K, 600 LUX	-31.55556	42.99552	10.13414	-52.93672	-10.17439	-3.114	17	.006
Pair 13	CP: 4600 K, 600 LUX - CP: 2700 K, 300 LUX	39.11111	36.83331	8.68169	20.79434	57.42789	4.505	17	.000

***Table C17*:** Shows the "TN" mean values and the outcomes of the t-test of (similar CCT at two different lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	TN: 6500 K, 300 LUX - TN: 6500 K, 600 LUX	-64.27778	45.30265	10.67794	-86.80626	-41.74930	-6.020	17	.000
Pair 10	TN: 4600 K, 300 LUX - TN: 4600 K, 600 LUX	-50.11111	35.37511	8.33799	-67.70274	-32.51948	-6.010	17	.000
Pair 15	TN: 2700 K, 300 LUX - TN: 2700 K, 600 LUX	-25.38889	68.13580	16.05976	-59.27202	8.49425	-1.581	17	.132

***Table C18*:** Shows the "EO" mean values and the outcomes of the t-test of (similar CCT at two different lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	EO: 6500 K, 300 LUX - EO: 6500 K, 600 LUX	12.22222	10.46313	2.46618	7.01903	17.42542	4.956	17	.000
Pair 10	EO: 4600 K, 300 LUX - EO: 4600 K, 600 LUX	11.16667	10.00147	2.35737	6.19305	16.14028	4.737	17	.000
Pair 15	EO: 2700 K, 300 LUX - EO: 2700 K, 600 LUX	19.77778	14.29338	3.36898	12.66985	26.88571	5.871	17	.000

***Table C19*:** Shows the "EC" mean values and the outcomes of the t-test of (similar CCT at two different lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	EC: 6500 K, 300 LUX - EC: 6500 K, 600 LUX	.05556	1.10997	.26162	-.49642	.60753	.212	17	.834
Pair 10	EC: 4600 K, 300 LUX - EC: 4600 K, 600 LUX	.66667	1.68034	.39606	-.16894	1.50228	1.683	17	.111
Pair 15	EC: 2700 K, 300 LUX - EC: 2700 K, 600 LUX	1.05556	1.62597	.38325	.24698	1.86413	2.754	17	.014

***Table C20*:** Shows the "E%" mean values and the outcomes of the t-test of (similar CCT at two different lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	E%: 6500 K, 300 LUX - E%: 6500 K, 600 LUX	2.78889	1.55484	.36648	2.01569	3.56209	7.610	17	.000
Pair 10	E%: 4600 K, 300 LUX - E%: 4600 K, 600 LUX	2.55000	1.76677	.41643	1.67141	3.42859	6.123	17	.000
Pair 15	E%: 2700 K, 300 LUX - E%: 2700 K, 600 LUX	3.72778	2.29008	.53978	2.58895	4.86661	6.906	17	.000

***Table C21*:** Shows the "CP" mean values and the outcomes of the t-test of (similar CCT at two different lx).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	CP: 6500 K, 300 LUX - CP: 6500 K, 600 LUX	-48.22222	19.87477	4.68453	-58.10571	-38.33873	-10.294	17	.000
Pair 10	CP: 4600 K, 300 LUX - CP: 4600 K, 600 LUX	-38.50000	23.60272	5.56321	-50.23735	-26.76265	-6.920	17	.000
Pair 15	CP: 2700 K, 300 LUX - CP: 2700 K, 600 LUX	-32.16667	31.20567	7.35525	-47.68488	-16.64845	-4.373	17	.000

***Table C22*:** Shows the mood effect of the first condition through the mean values and the outcomes of the t-test of PA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	PA (before): 6500 K 300 LUX - PA (After): 6500 K 300 LUX	-.27778	6.84110	1.61246	-3.67978	3.12422	-.172	17	.865

***Table C23*:** Shows the mood effect of the first condition through the mean values and the outcomes of the t-test of NA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	NA (before): 6500 K 300 LUX - NA (After): 6500 K 300 LUX	.05556	5.11598	1.20585	-2.48856	2.59967	.046	17	.964

***Table C24*: Shows the mood effect of the second condition through the mean values and the outcomes of the t-test of PA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 2	PA (before): 6500 K 600 LUX - PA (After): 6500 K 600 LUX	.16667	5.22719	1.23206	-2.43275	2.76609	.135	17	.894

***Table C25*: Shows the mood effect of the second condition through the mean values and the outcomes of the t-test of NA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 2	NA (before): 6500 K 600 LUX - NA (After): 6500 K 600 LUX	-1.61111	5.04263	1.18856	-4.11875	.89653	-1.356	17	.193

***Table C26*:** Shows the mood effect of the third condition through the mean values and the outcomes of the t-test of PA (before and after).

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 3	PA (before): 4600 K 300 LUX - PA (After): 4600 K 300 LUX	.00000	7.15377	1.68616	-3.55749	3.55749	.000	17	1.000

***Table C27*:** Shows the mood effect of the third condition through the mean values and the outcomes of the t-test of NA (before and after).

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 3	NA (before): 4600 K 300 LUX - NA (After): 4600 K 300 LUX	-2.44444	5.89339	1.38908	-5.37516	.48627	-1.760	17	.096

***Table C28*:** Shows the mood effect of the fourth condition through the mean values and the outcomes of the t-test of PA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 4	PA (before): 4600 K 600 LUX - PA (After): 4600 K 600 LUX	3.00000	4.81419	1.13472	.60596	5.39404	2.644	17	.017

***Table C29*:** Shows the mood effect of the fourth condition through the mean values and the outcomes of the t-test of NA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 4	NA (before): 4600 K 600 LUX - NA (After): 4600 K 600 LUX	-1.50000	2.70620	.63786	-2.84576	-.15424	-2.352	17	.031

***Table C30*:** Shows the mood effect of the fifth condition through the mean values and the outcomes of the t-test of PA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 5	PA (before): 2700 K 300 LUX - PA (After): 2700 K 300 LUX	1.83333	6.36396	1.50000	-1.33139	4.99806	1.222	17	.238

***Table C31*:** Shows the mood effect of the fifth condition through the mean values and the outcomes of the t-test of NA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 5	NA (before): 2700 K 300 LUX - NA (After): 2700 K 300 LUX	-.05556	8.58502	2.02351	-4.32479	4.21368	-.027	17	.978

Table C32**:** Shows the mood effect of the sixth condition through the mean values and the outcomes of the t-test of PA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 6	PA (before): 2700 K 600 LUX - PA (After): 2700 K 600 LUX	1.11111	5.02803	1.18512	-1.38927	3.61149	.938	17	.362

Table C33**:** Shows the mood effect of the sixth condition through the mean values and the outcomes of the t-test of NA (before and after).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 6	NA (before): 2700 K 600 LUX - NA (After): 2700 K 600 LUX	-1.16667	4.68100	1.10332	-3.49447	1.16114	-1.057	17	.305

***Table C34*:** Shows the Pearson correlation test between PANAS values and d2 test of attention values of the first condition.

Correlations					
	Pearson Correlation		**Sig. (2-tailed)**		**N**
	Delta (PA)	**Delta (NA)**	**Delta (PA)**	**Delta (NA)**	
TN	0.359	-0.366	0.143	0.136	18
CP	0.32	-0.211	0.196	0.402	18
EO	0.18	-0.373	0.476	0.128	18
EC	-0.222	0.292	0.377	0.24	18
E	0.097	-0.307	0.703	0.216	18

***Table C35*:** Shows the Pearson correlation test between PANAS values and the d2 test of attention values of the second condition.

Correlations					
	Pearson Correlation		**Sig. (2-tailed)**		**N**
	Delta (PA)	**Delta (NA)**	**Delta (PA)**	**Delta (NA)**	
TN	0.218	-0.075	0.385	0.766	18
CP	0.165	-0.012	0.513	0.963	18
EO	0.136	-0.122	0.591	0.631	18
EC	-0.126	-0.322	0.617	0.192	18
E	0.115	-0.103	0.648	0.685	18

***Table C36*:** Shows the Pearson correlation test between PANAS values and the d2 test of attention values of the third condition.

Correlations					
	Pearson Correlation		**Sig. (2-tailed)**		**N**
	Delta (PA)	**Delta (NA)**	**Delta (PA)**	**Delta (NA)**	
TN	-0.343	0.265	0.164	0.288	18
CP	-0.185	0.165	0.463	0.514	18
EO	-0.33	0.259	0.18	0.299	18
EC	-0.445	0.211	0.065	0.4	18
E	-0.326	0.258	0.187	0.301	18

***Table C37*:** Shows the Pearson correlation test between PANAS values and the d2 test of attention values of the fourth condition.

Correlations					
	Pearson Correlation		**Sig. (2-tailed)**		**N**
	Delta (PA)	**Delta (NA)**	**Delta (PA)**	**Delta (NA)**	
TN	0.244	-0.192	0.329	0.445	18
CP	0.102	-0.261	0.686	0.296	18
EO	0.179	0.096	0.478	0.705	18
EC	0.517	-0.088	0.028	0.728	18
E	0.195	0.132	0.437	0.601	18

***Table C38*:** Shows the Pearson correlation test between PANAS values and the d2 test of attention values of the fifth condition.

Correlations					
	Pearson Correlation		**Sig. (2-tailed)**		**N**
	Delta (PA)	**Delta (NA)**	**Delta (PA)**	**Delta (NA)**	
TN	-0.176	0.021	0.485	0.934	18
CP	-0.213	-0.054	0.397	0.832	18
EO	-0.004	0.092	0.987	0.717	18
EC	0.133	-0.287	0.6	0.248	18
E	0.021	0.112	0.933	0.66	18

Table C39**:** Shows the Pearson correlation test between PANAS values and d2 test of attention values of the sixth condition.

Correlations					
	Pearson Correlation		**Sig. (2-tailed)**		**N**
	Delta (PA)	**Delta (NA)**	**Delta (PA)**	**Delta (NA)**	
TN	0.231	0.112	0.357	0.659	18
CP	0.375	0.004	0.125	0.988	18
EO	-0.415	0.279	0.087	0.262	18
EC	0.003	0.122	0.99	0.63	18
E	-0.448	0.267	0.062	0.283	18

APPENDIX D

Figure D1**:** Shows the D2 test of attention CP results for all conditions.

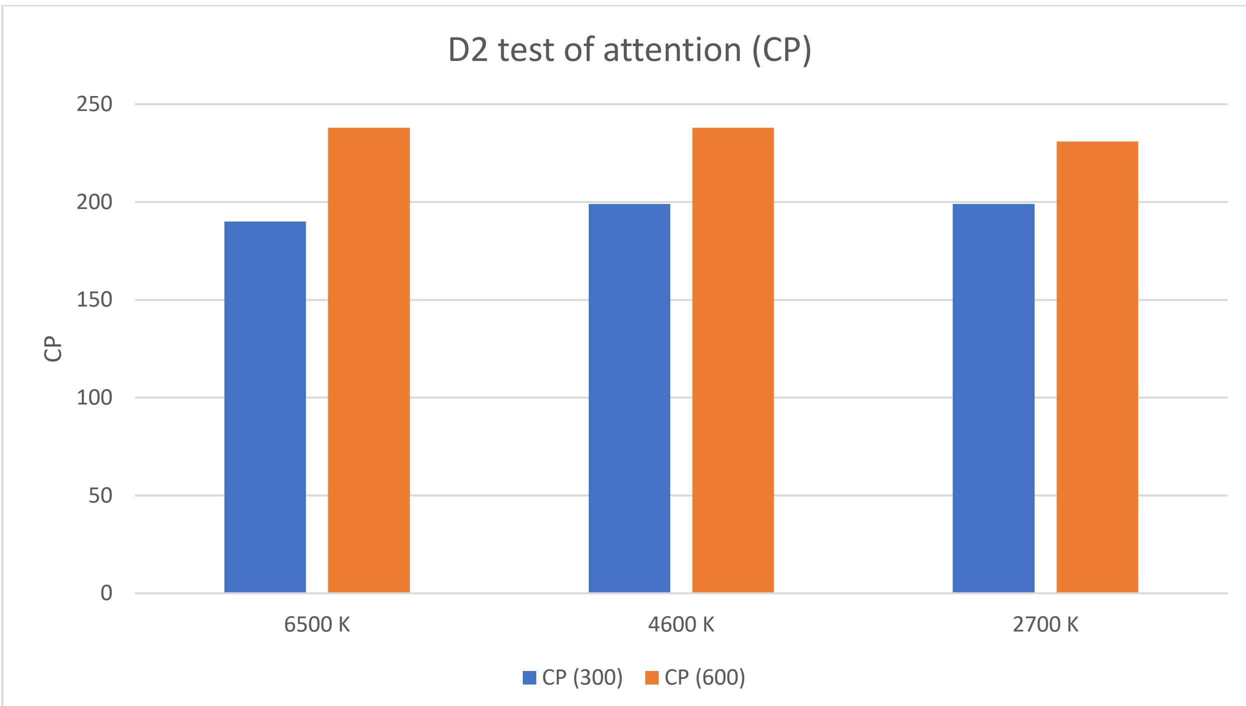


***Figure D2*:** Shows the D2 test of attention E% results for all conditions.

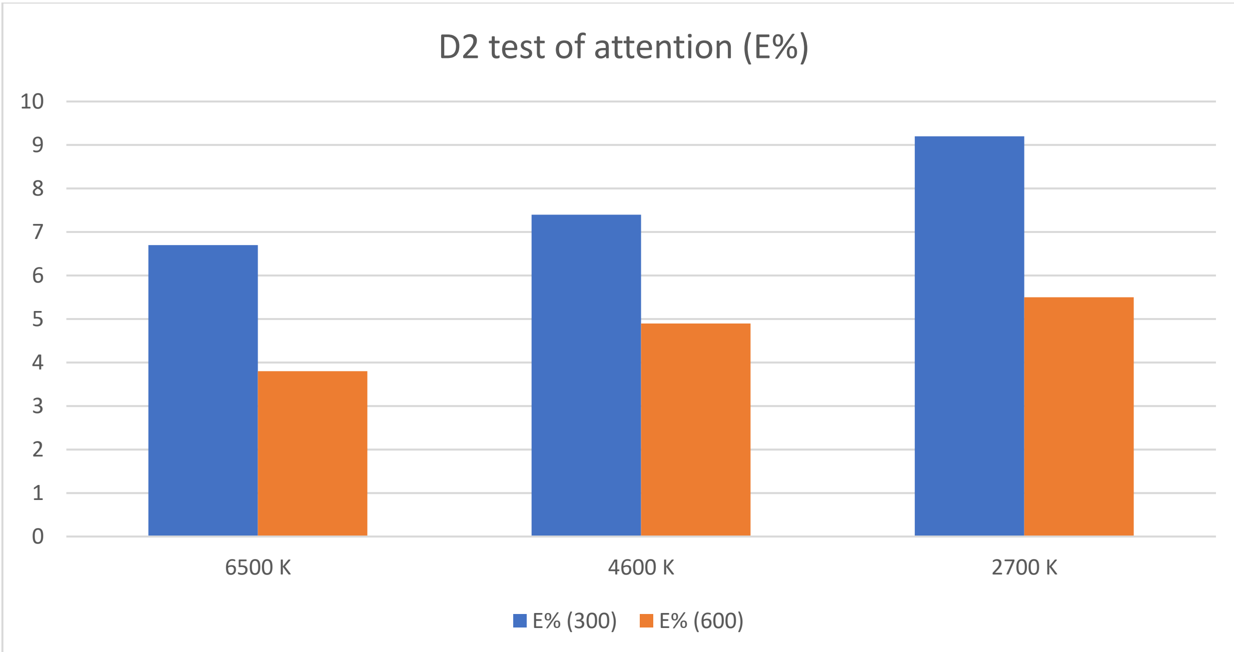


***Figure D3*:** Shows the D2 test of attention TN results for all conditions.

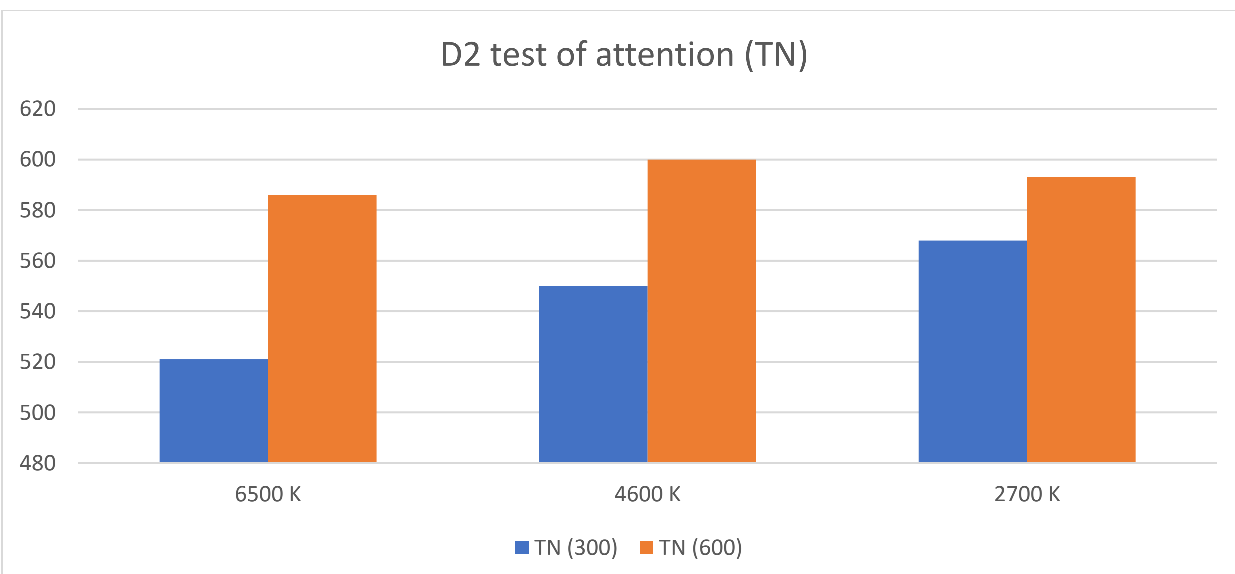


Figure D4**:** Shows the D2 test of attention EC results for all conditions.

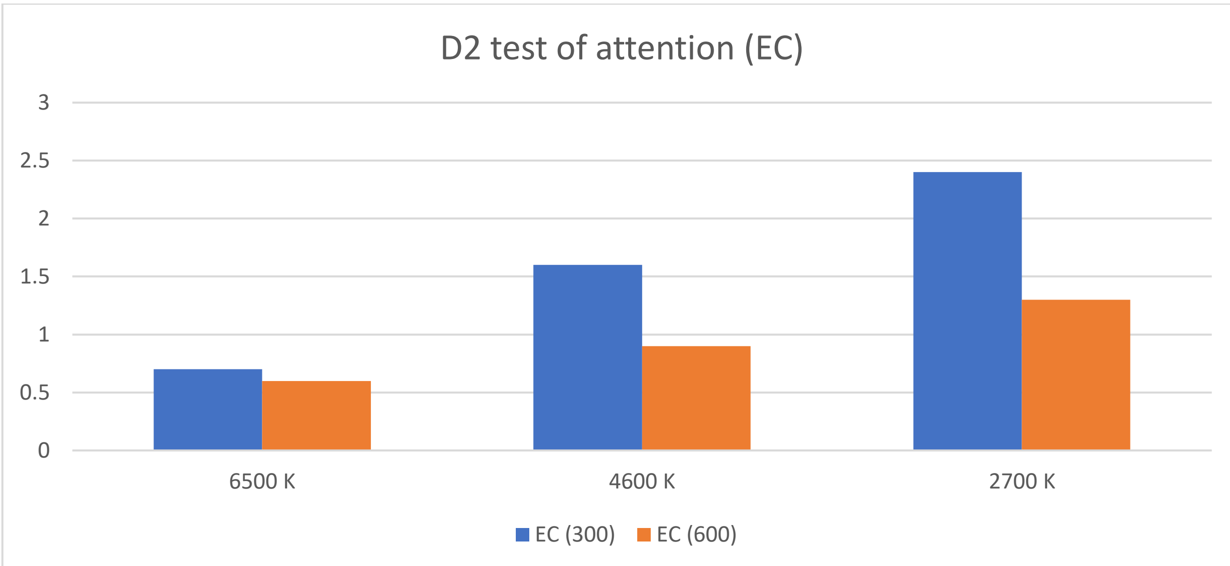


Figure D5**:** Shows the D2 test of attention EO results for all conditions.

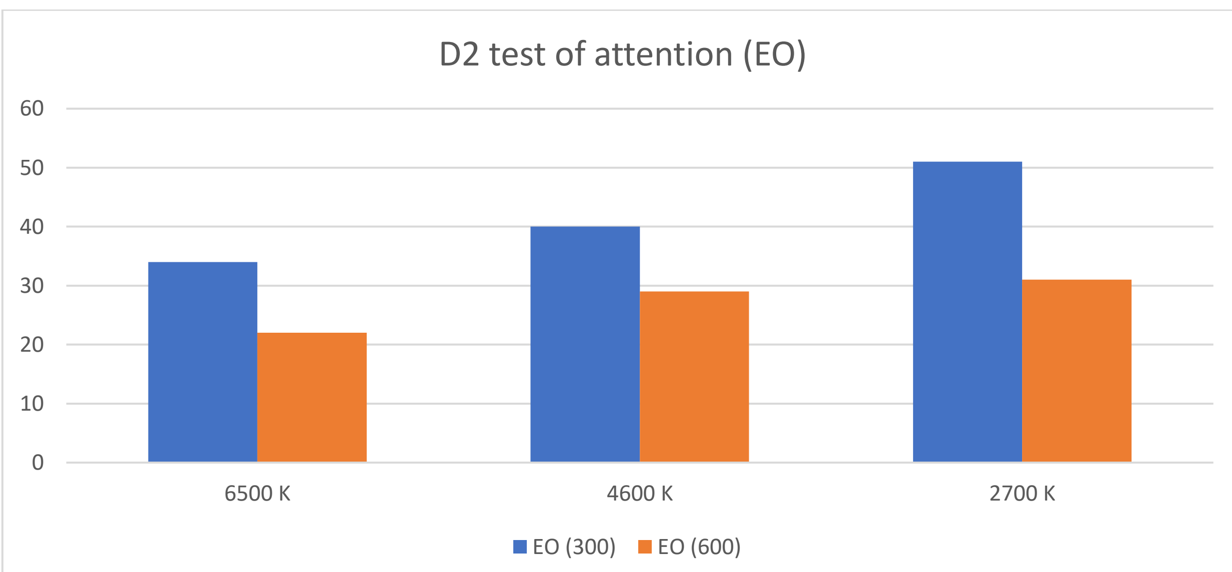


Figure D6**:** Shows the PANAS test results (before/after) for the first condition.

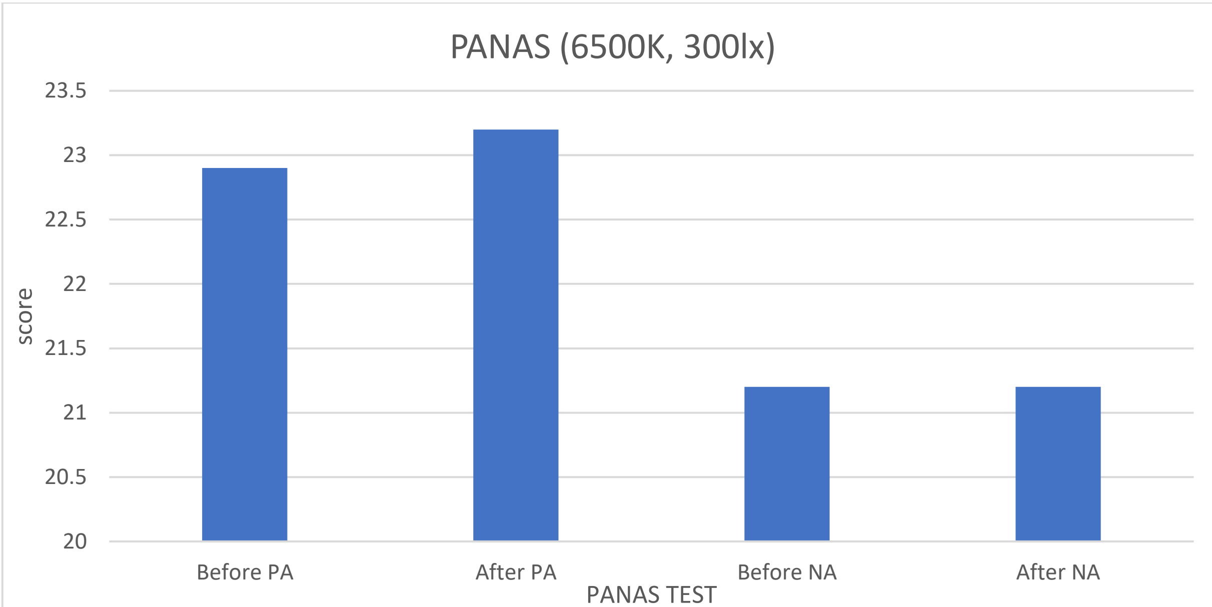


Figure D7**:** Shows the PANAS test results (before/after) for the second condition.

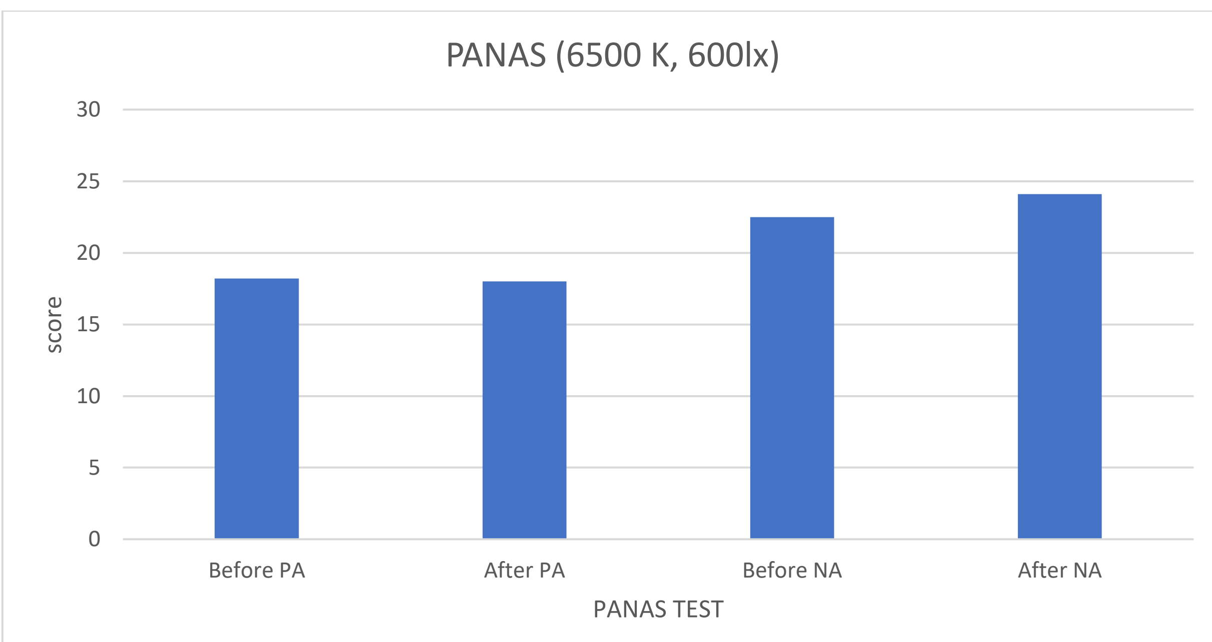


***Figure D8*:** Shows the PANAS test results (before/after) for the third condition.

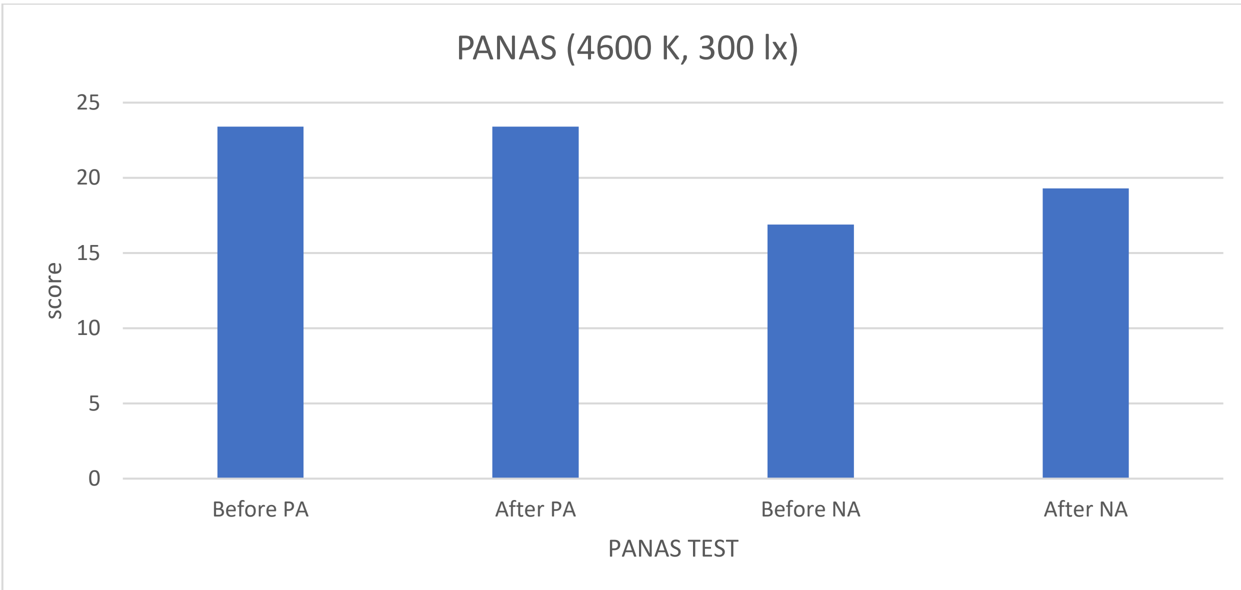


***Figure D9*:** Shows the PANAS test results (before/after) for the fourth condition.

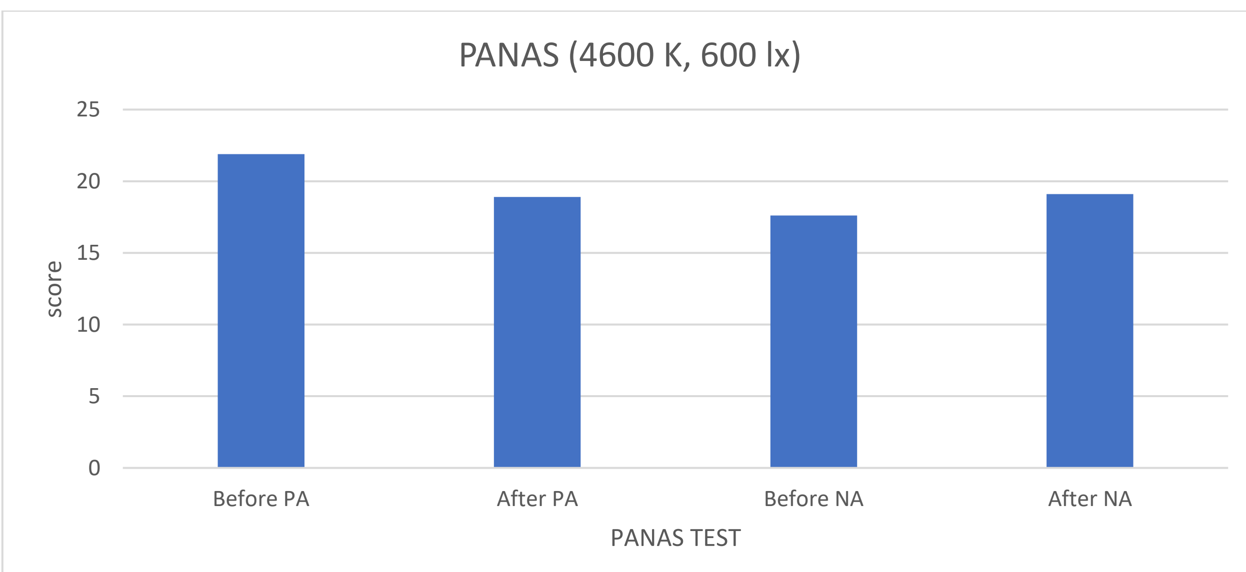


***Figure D10*:** Shows the PANAS test results (before/after) for the fifth condition.

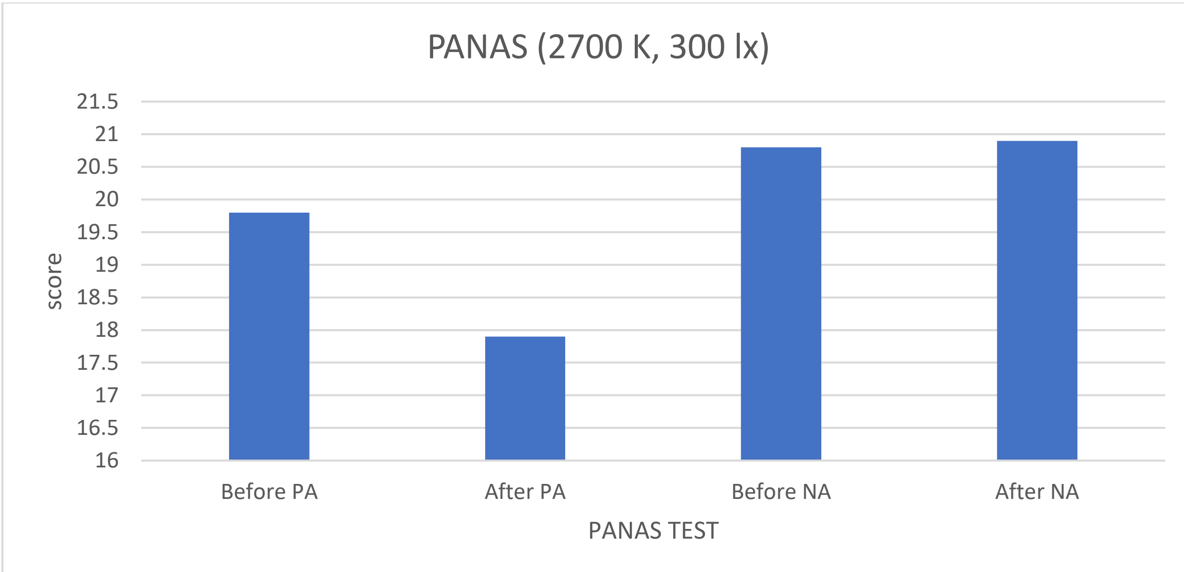


***Figure D11*:** Shows the PANAS test results (before/after) for the sixth condition.

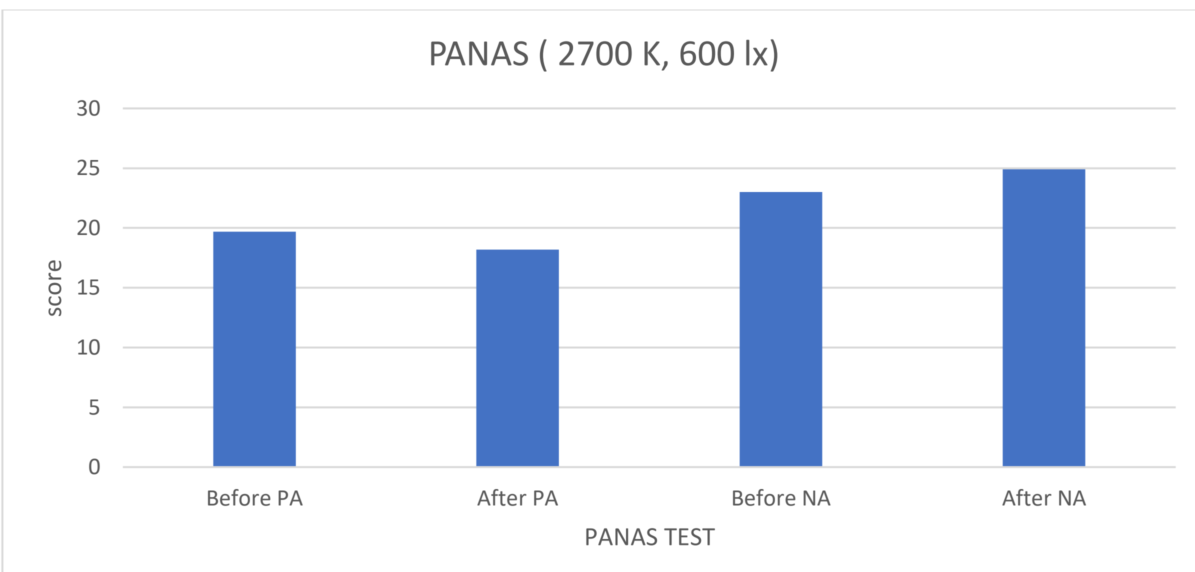


***Figure D12*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and CP for condition#1.

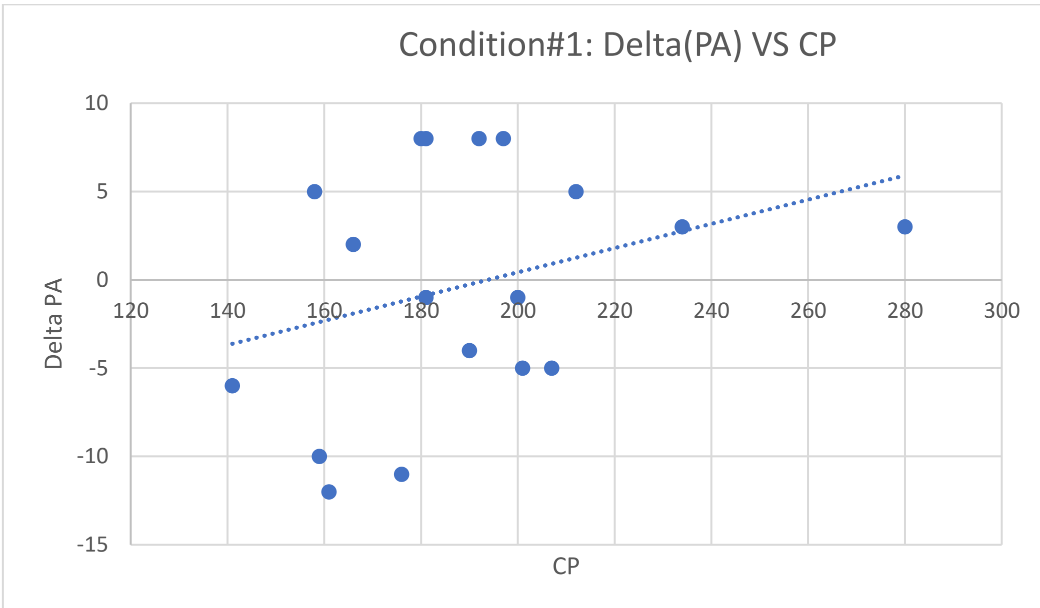


***Figure D13*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EC for condition#1.

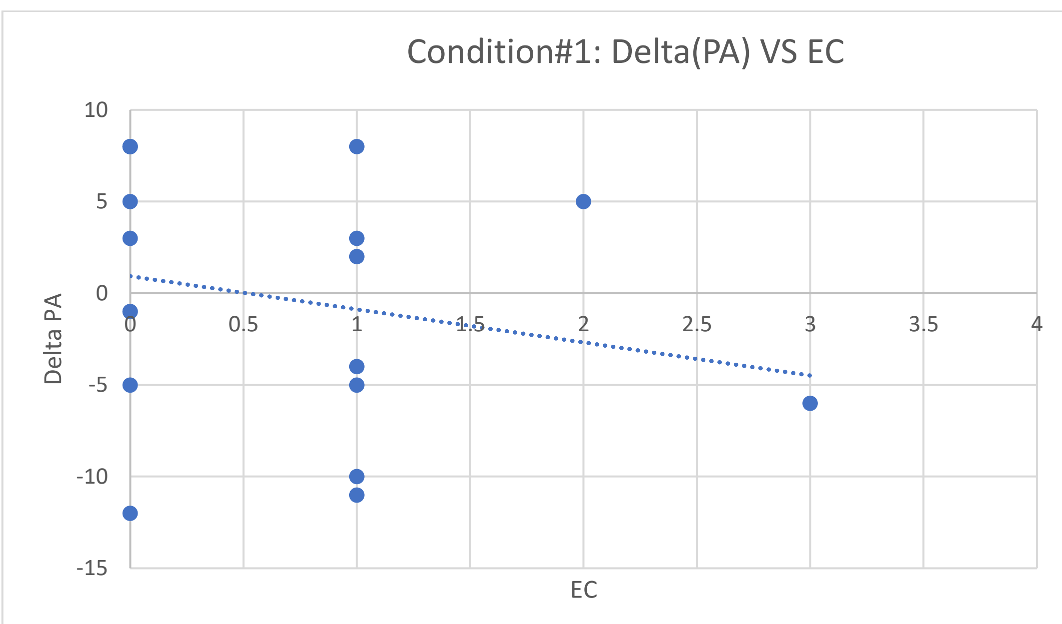


Figure D14**:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EO for condition#1.

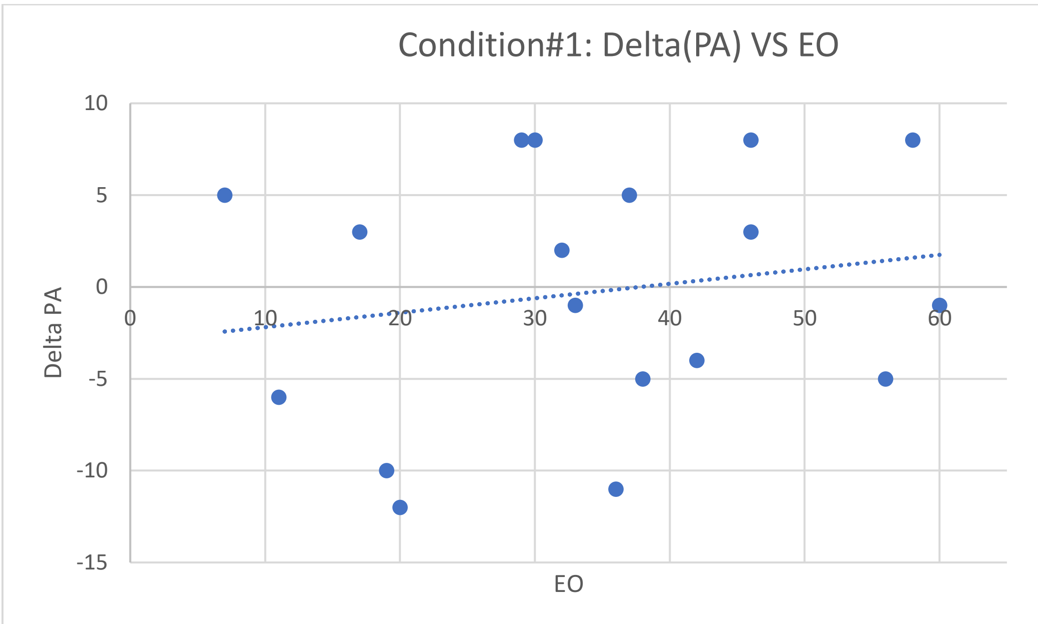


Figure D15**:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and CP for condition#1.

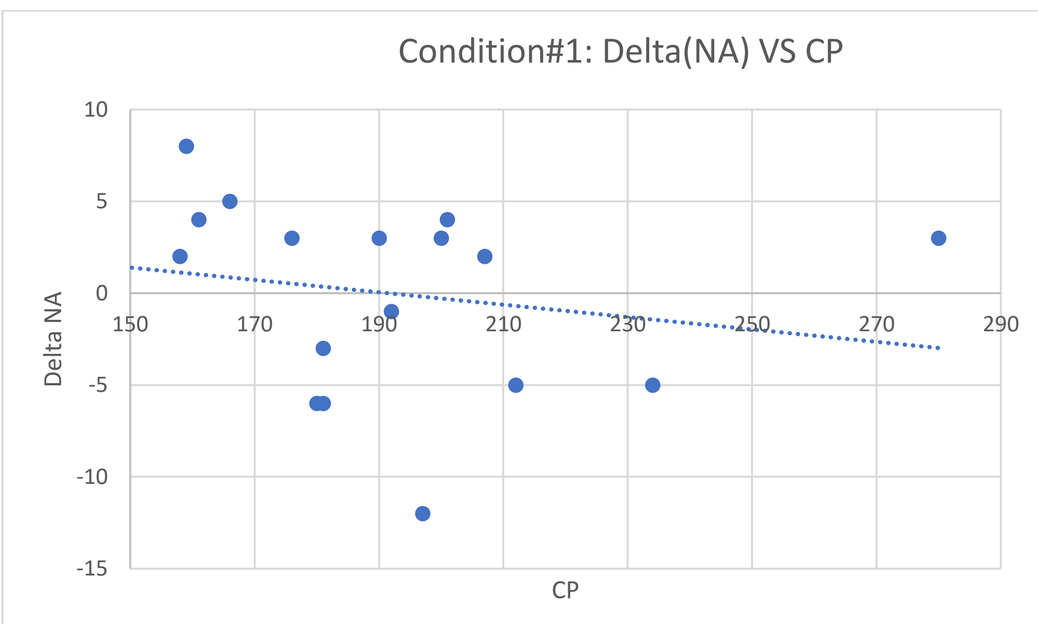


***Figure D16*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EO for condition#1.

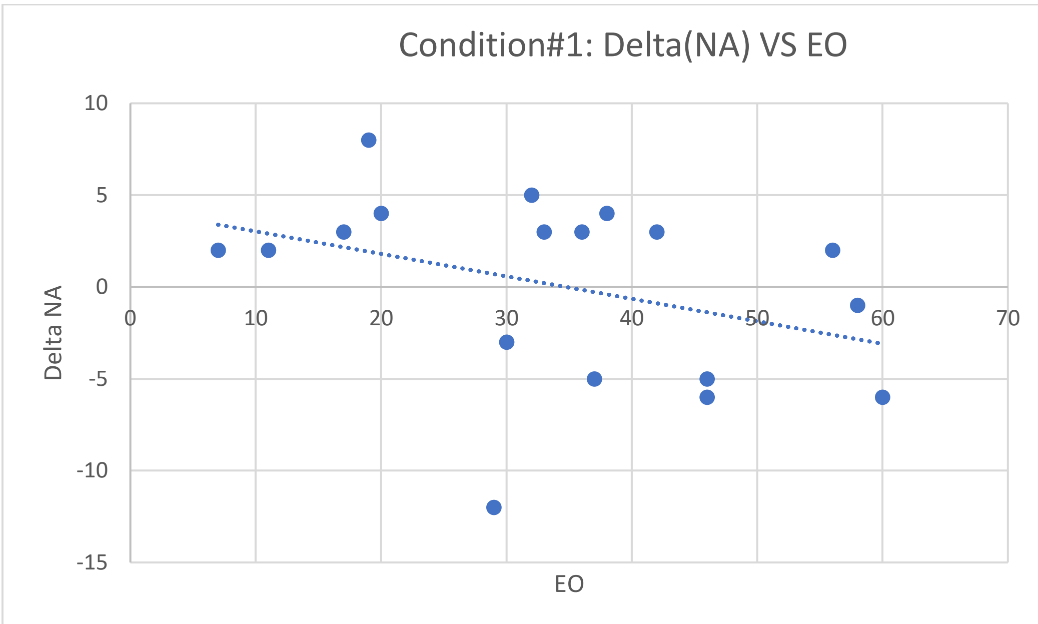


***Figure D17*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EC for condition#1.

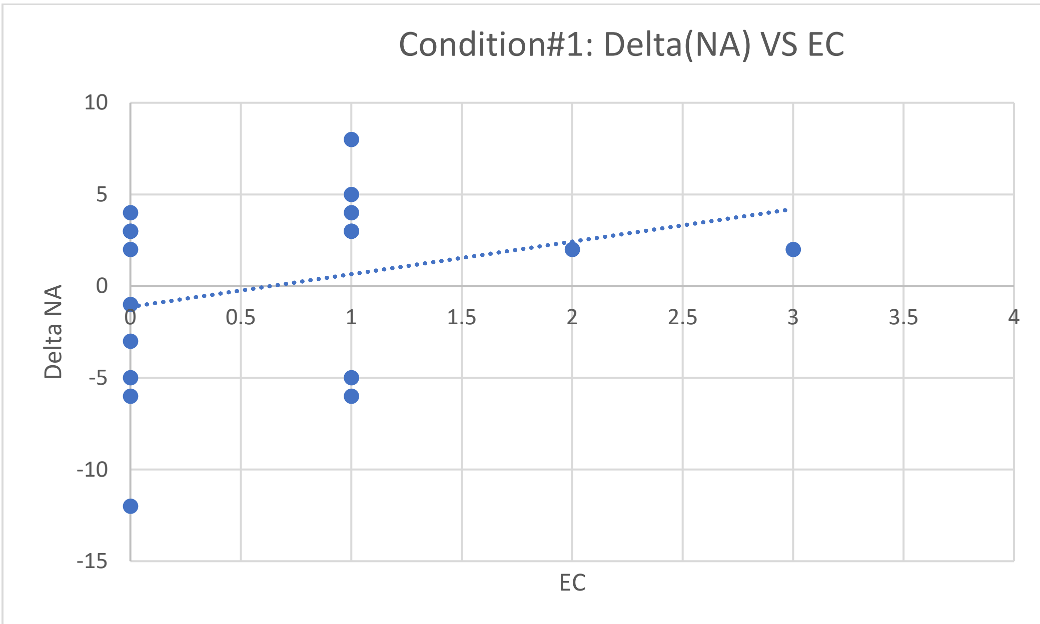


***Figure D18*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and CP for condition#2.

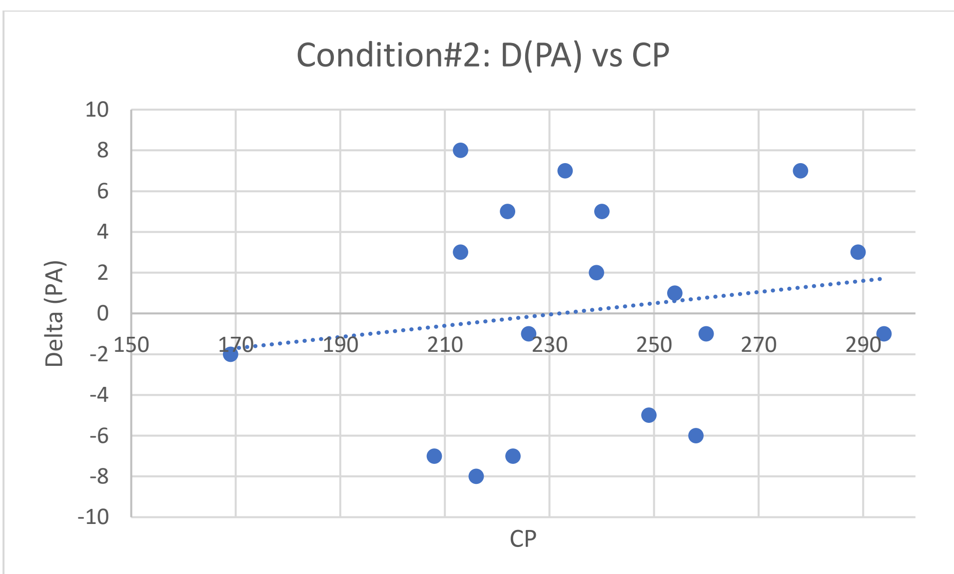


***Figure D19*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EO for condition#2.

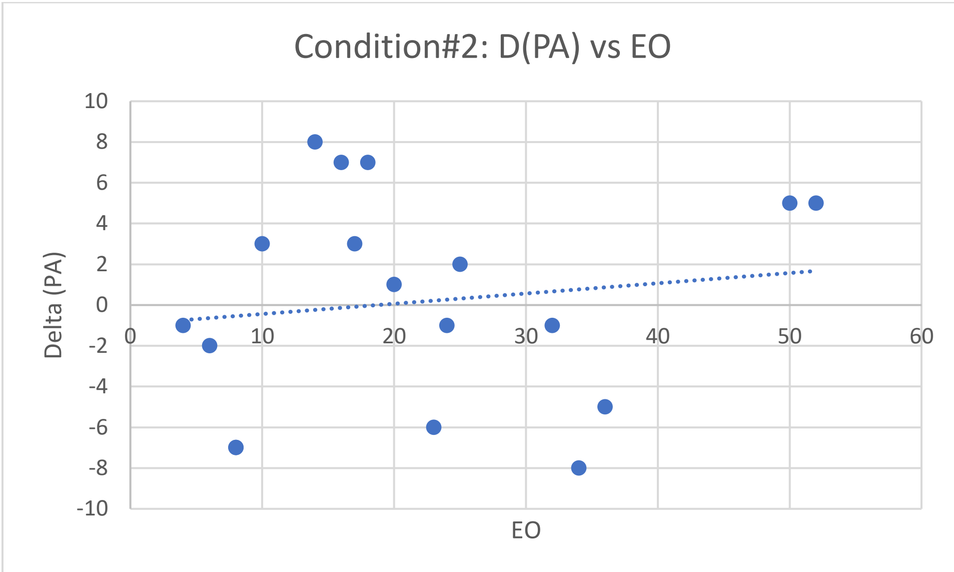


***Figure D20*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EC for condition#2.

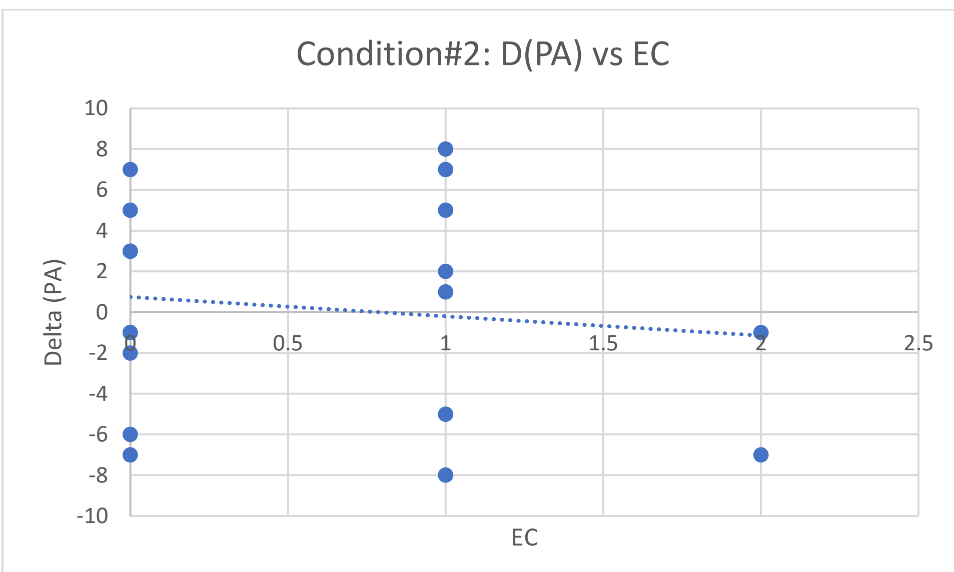


***Figure D21*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and CP for condition#2.

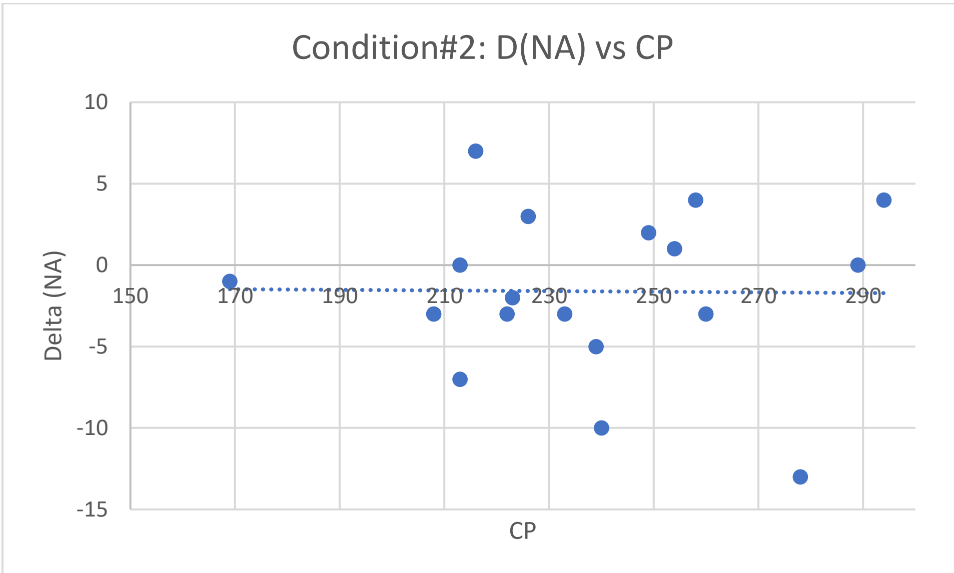


***Figure D22*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EO for condition#2.

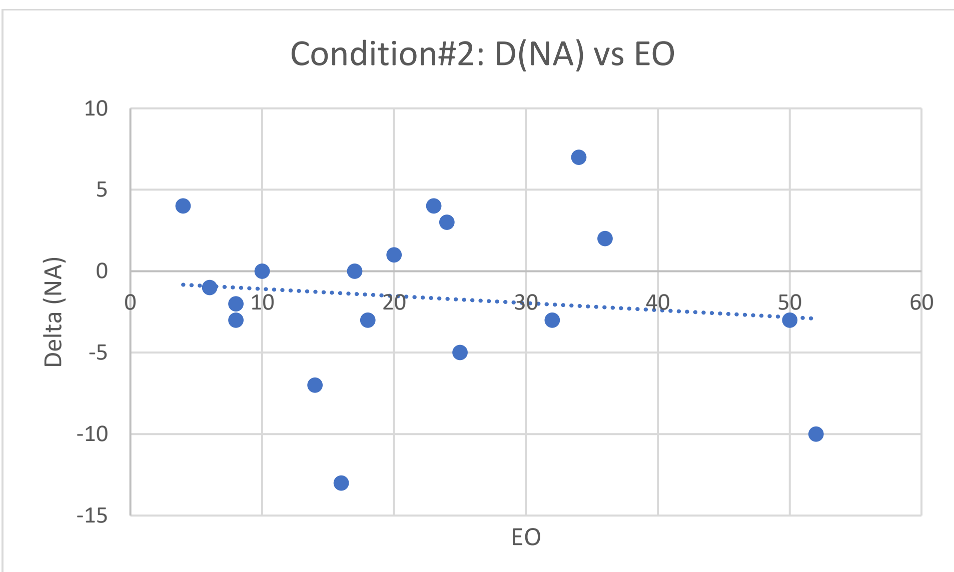


***Figure D23*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EC for condition#2.

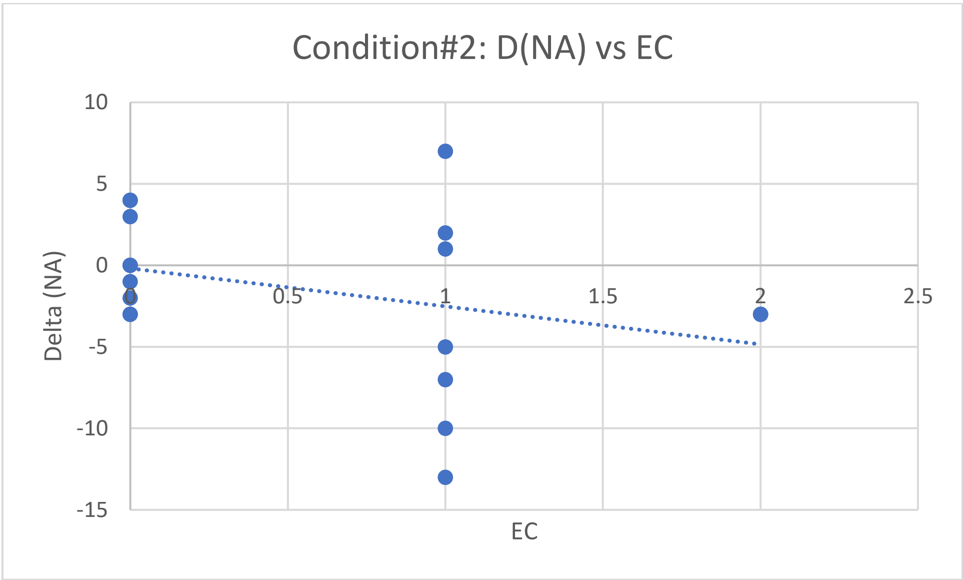


***Figure D24*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and CP for condition#3.

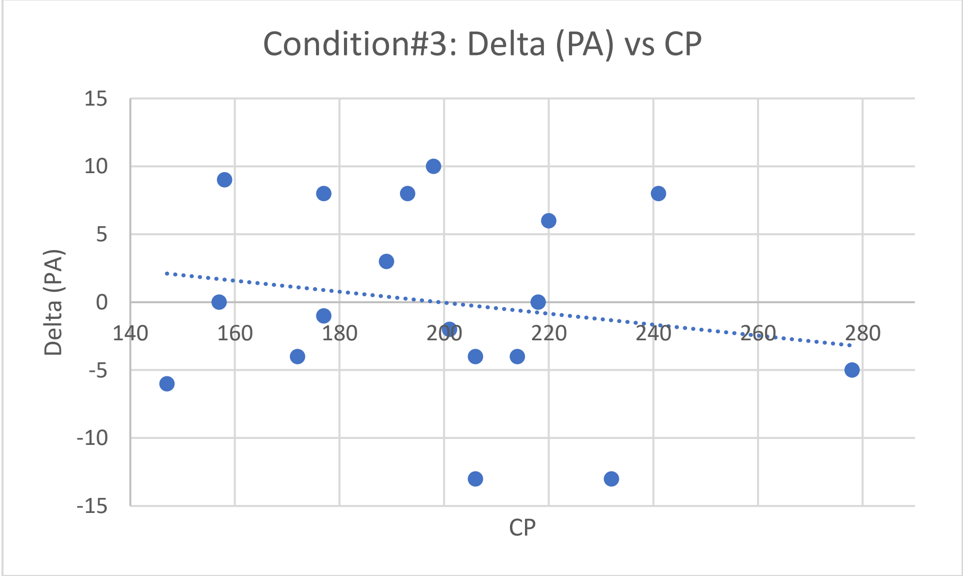


***Figure D25*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EO for condition#3.

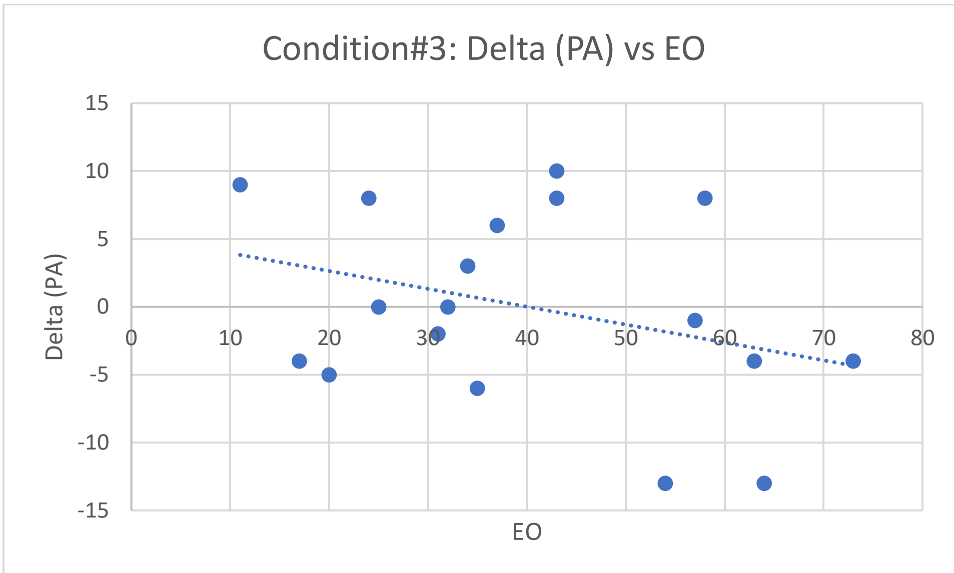


***Figure D26*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EC for condition#3.

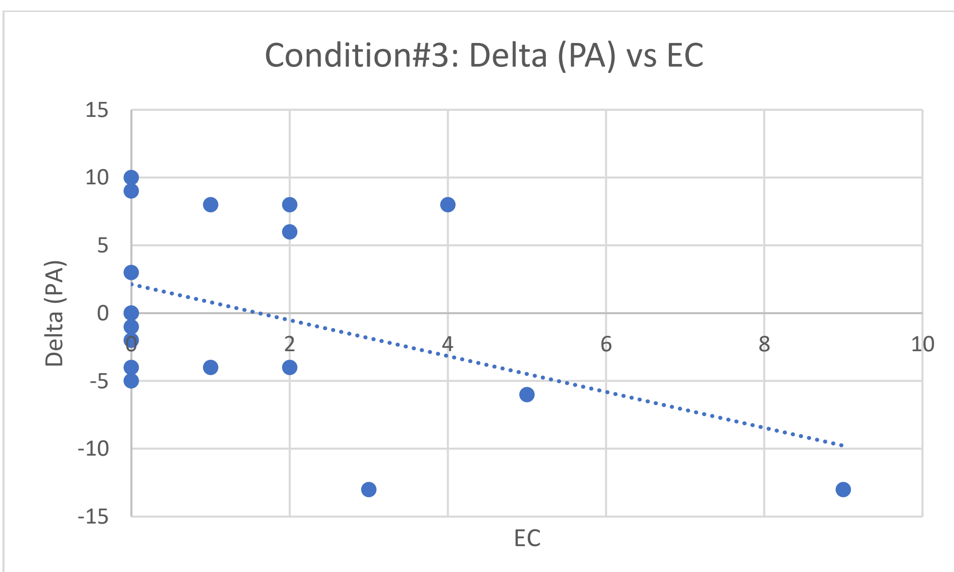


***Figure D27*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and CP for condition#3.

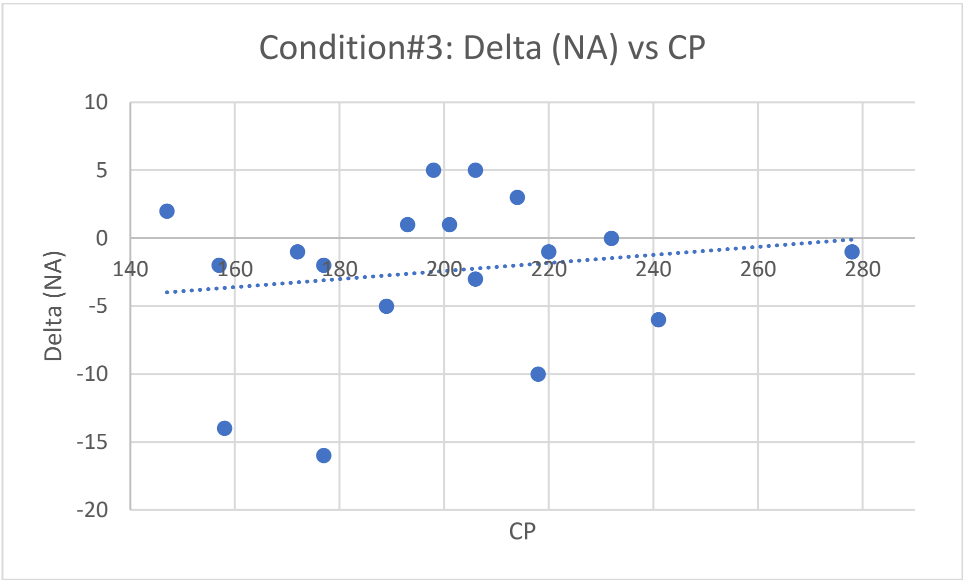


***Figure D28*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EO for condition#3.

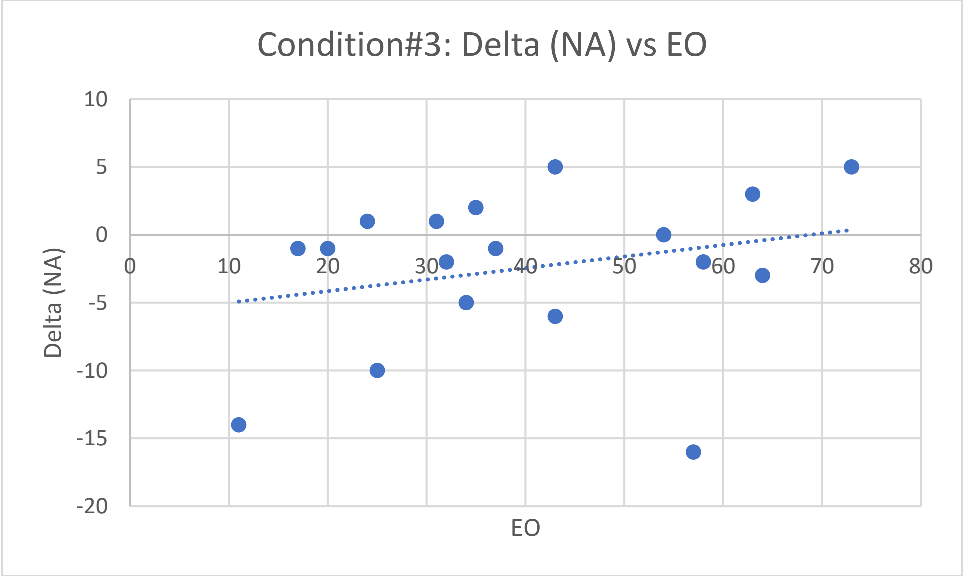


***Figure D29*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EC for condition#3.

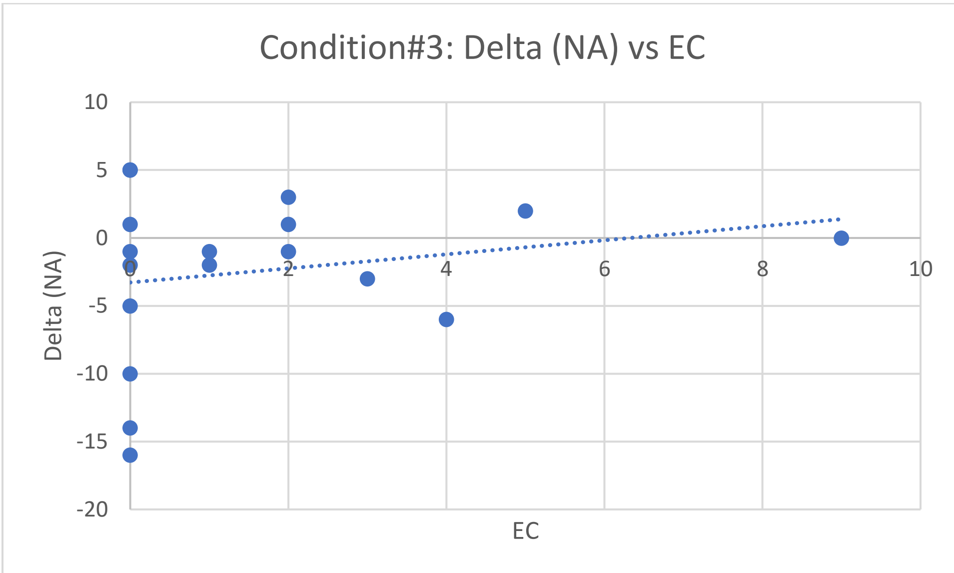


***Figure D30*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and CP for condition#4.

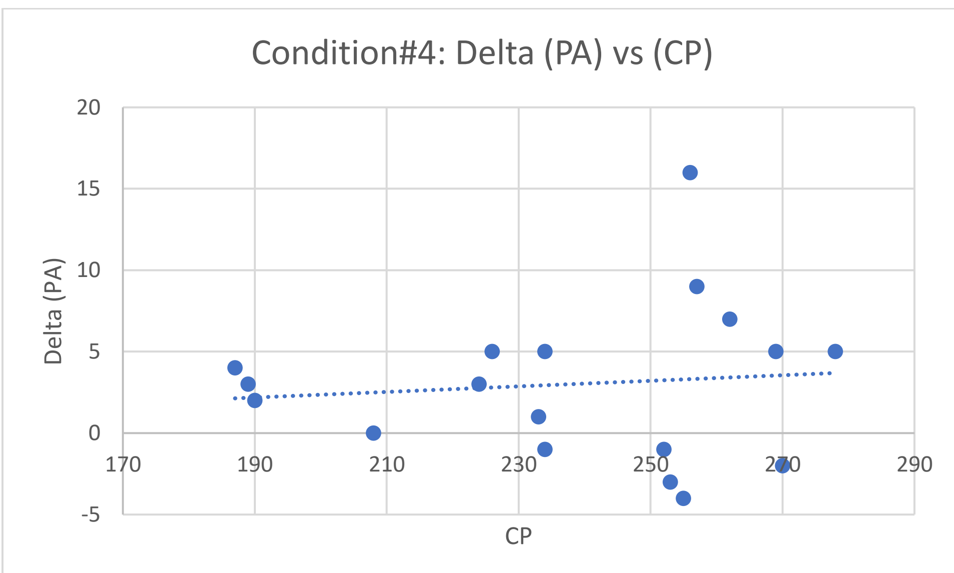


Figure D31**:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EO for condition#4.

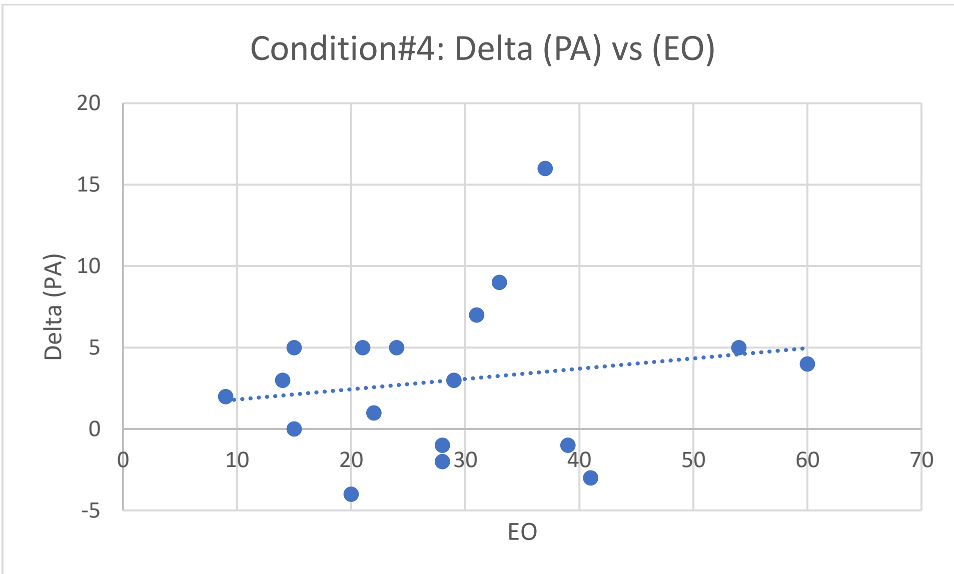


Figure D32**:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EC for condition#4.

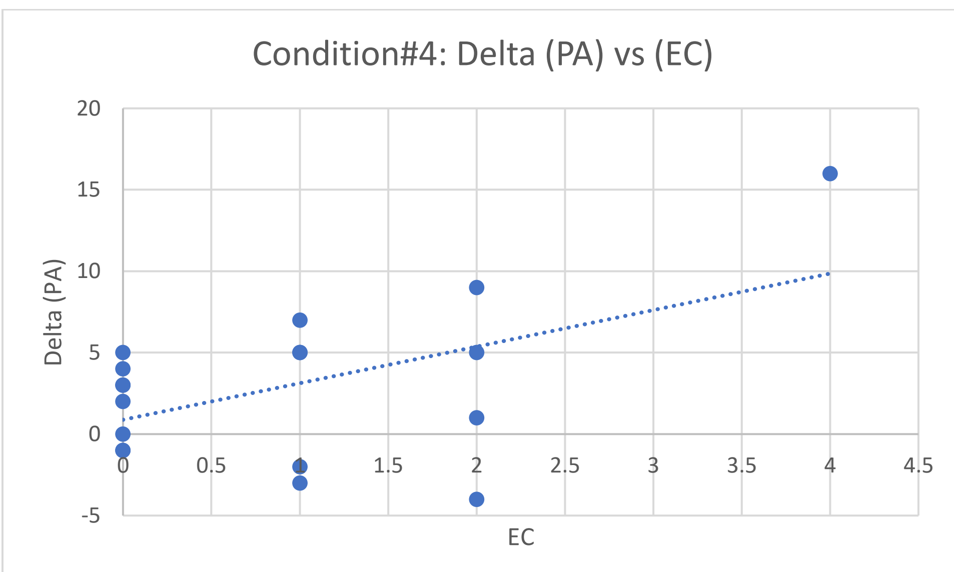


***Figure D33*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and CP for condition#4.

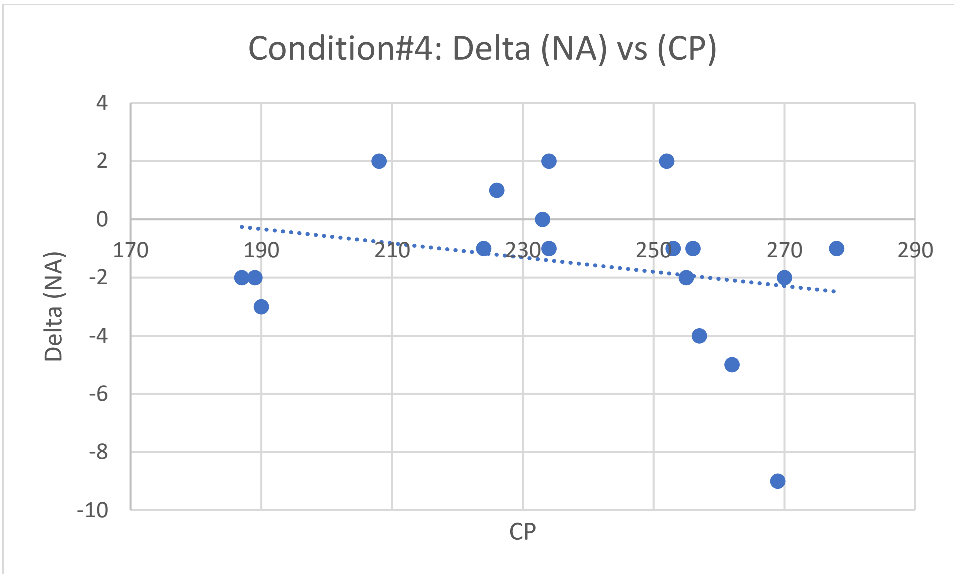


***Figure D34*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EO for condition#4.

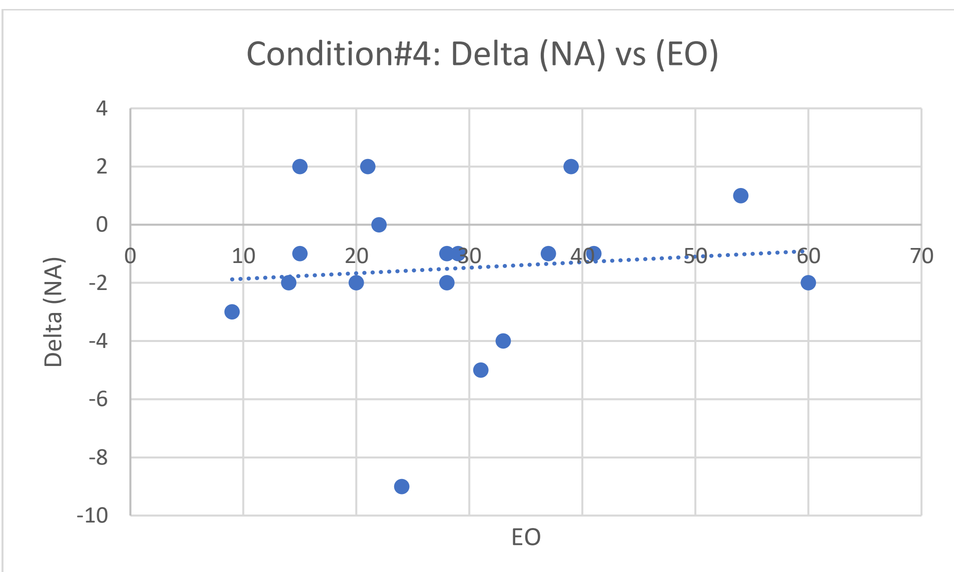


***Figure D35*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EC for condition#4.

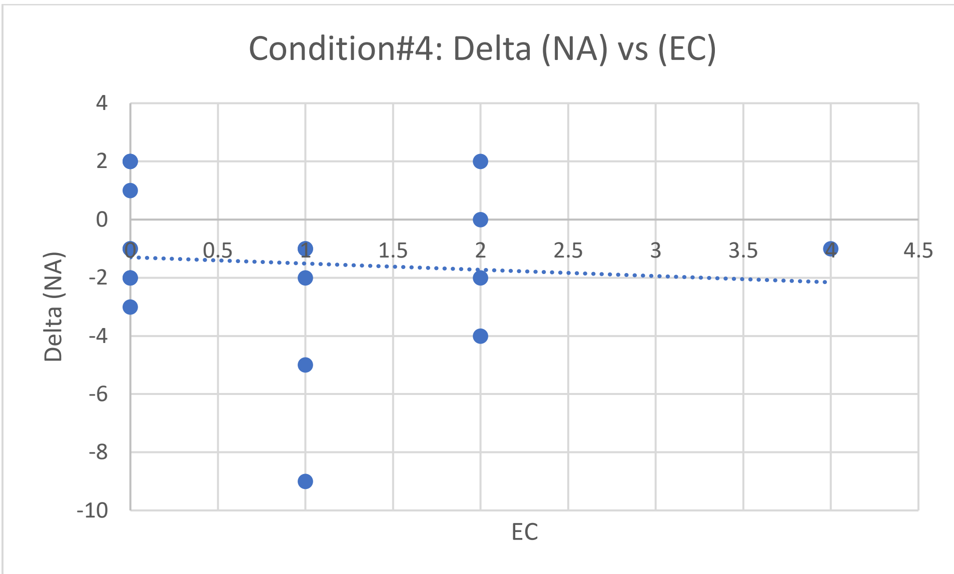


***Figure D36*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and CP for condition#5.

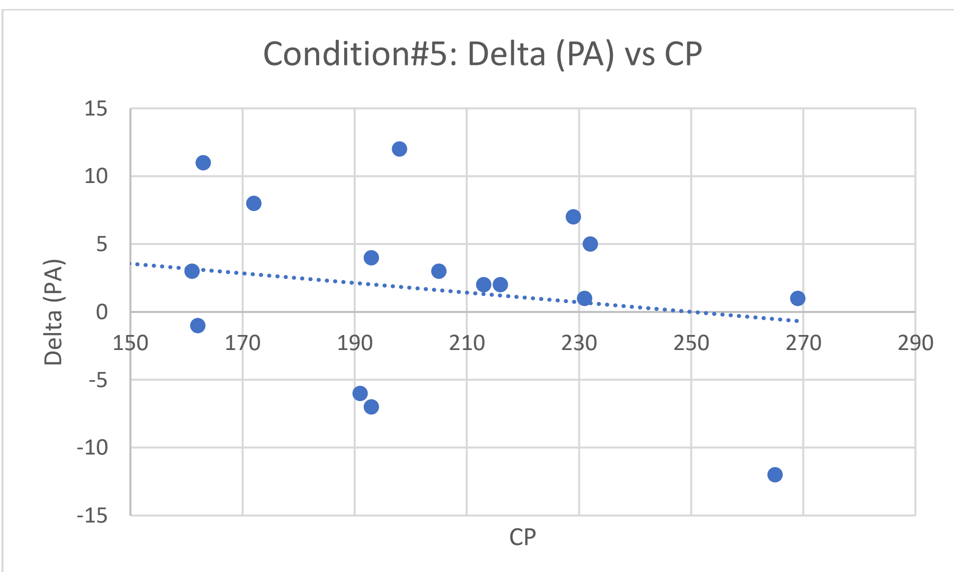


***Figure D37*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EO for condition#5.

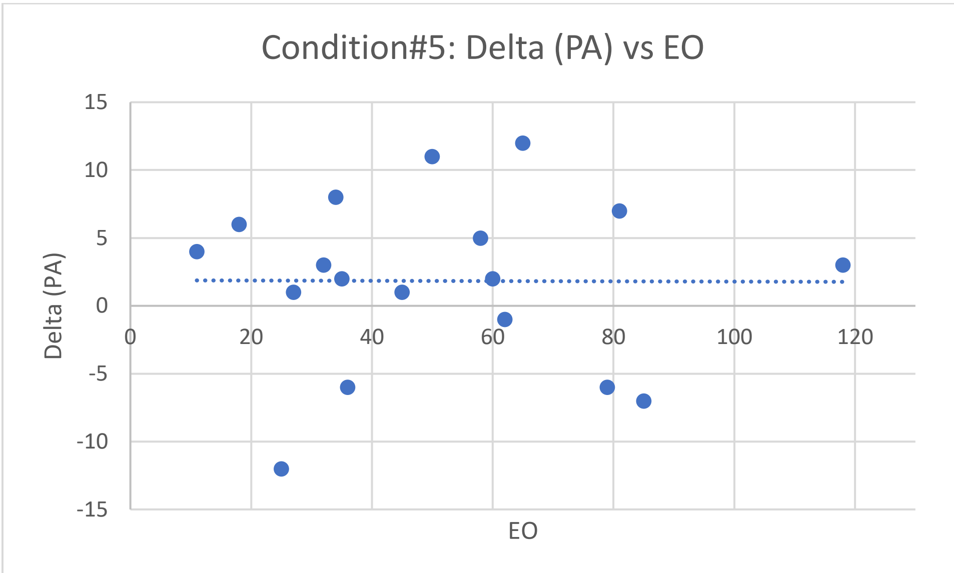


***Figure D38*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EC for condition#5.

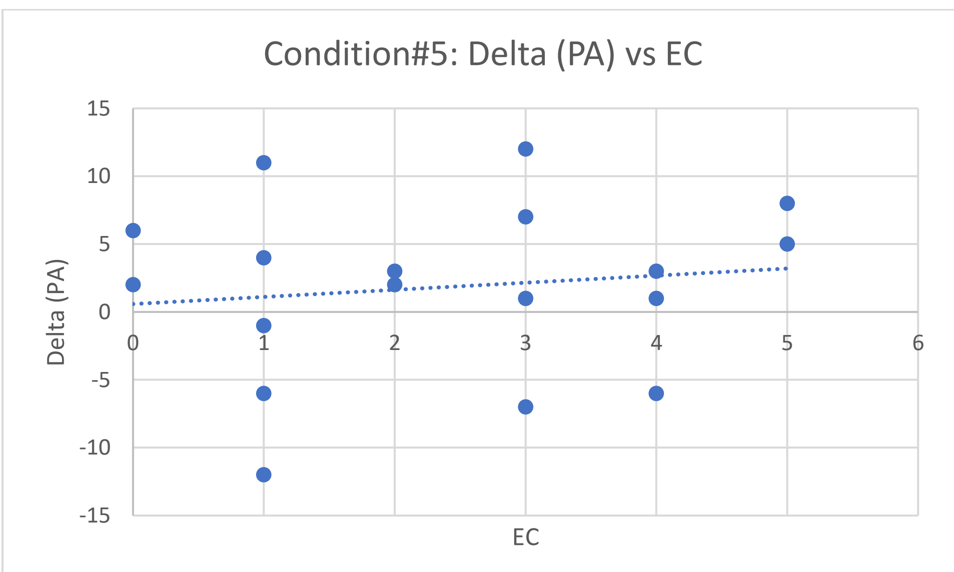


***Figure D39*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and CP for condition#5.

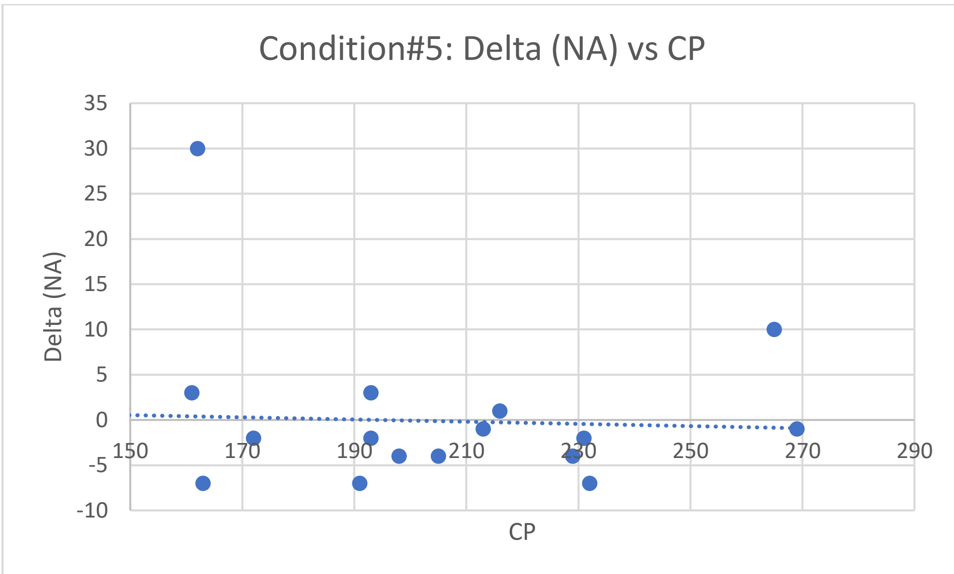


***Figure D40*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EO for condition#5.

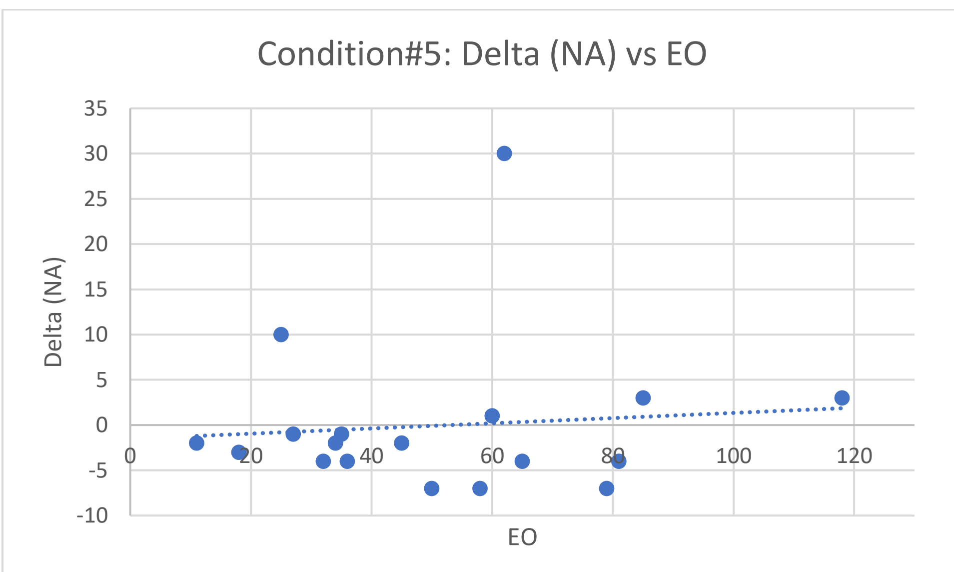


***Figure D41*: A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EC for condition#5.

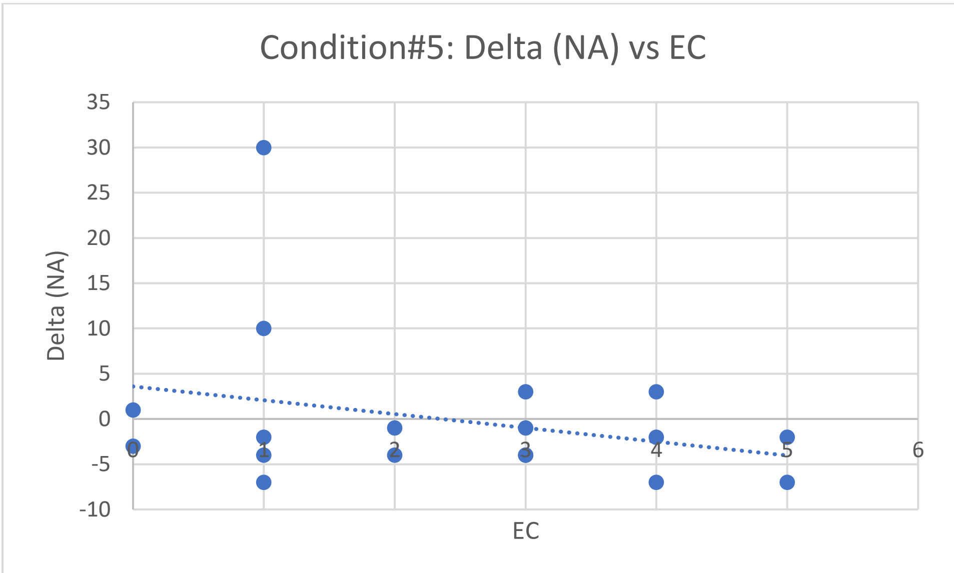


***Figure D42*: A plot (x/y axis) shows the correlations tests variables between Delta (PA) and CP for condition#6.

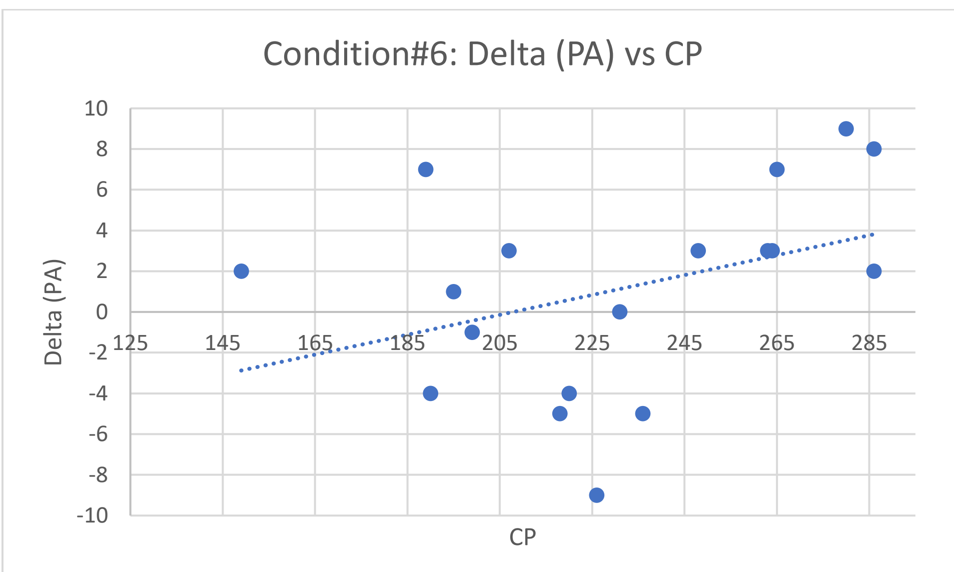


***Figure D43*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EO for condition#6.

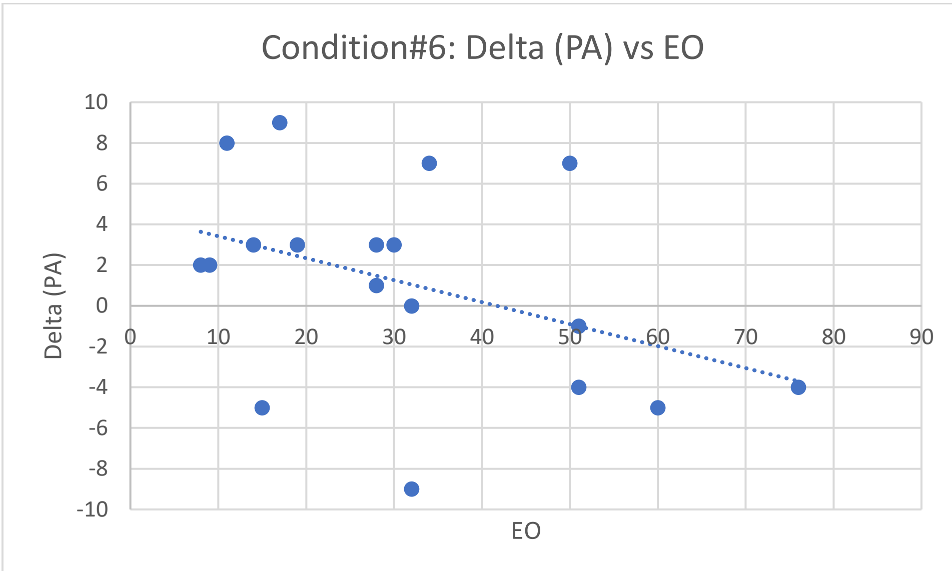


***Figure D44*:** A plot (x/y axis) shows the correlations tests variables between Delta (PA) and EC for condition#6.

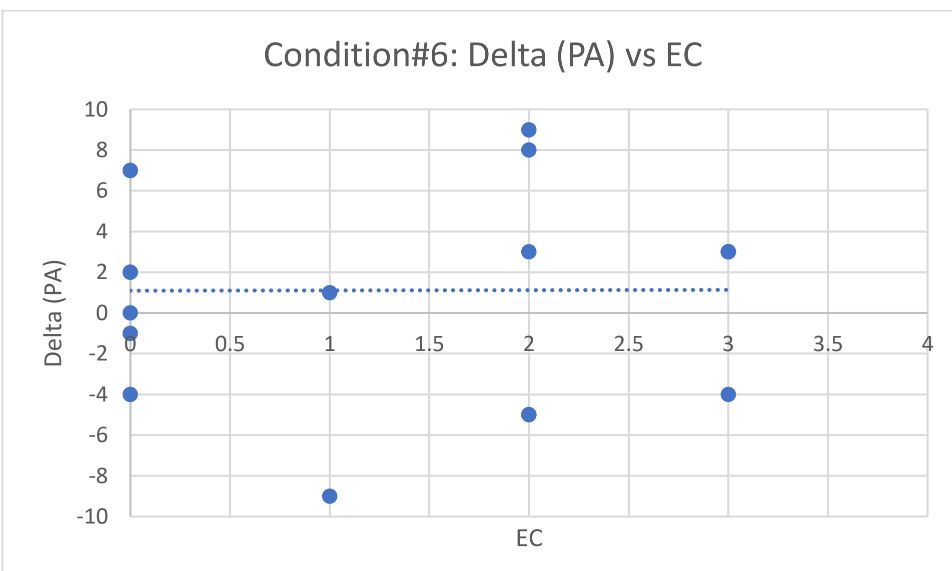


***Figure D45*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and CP for condition#6.

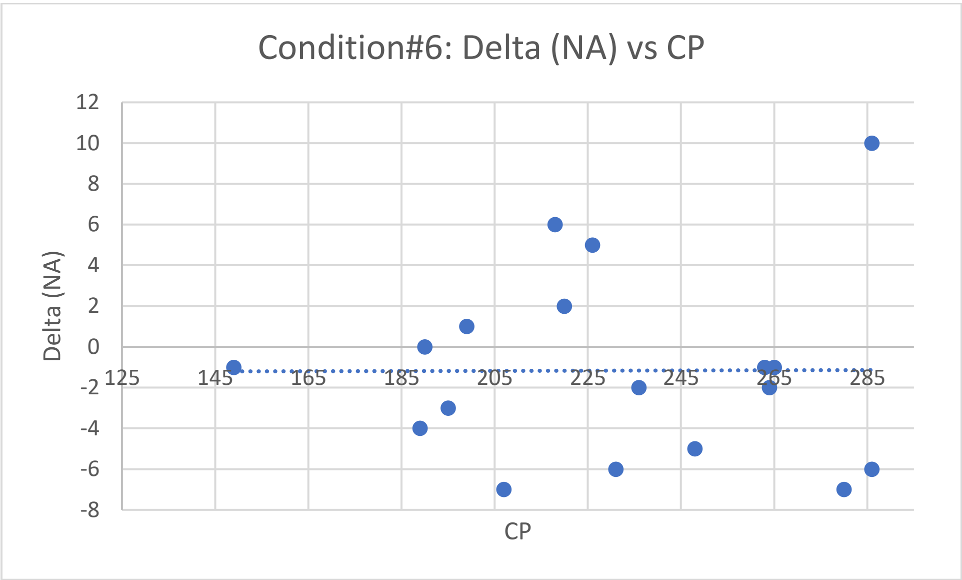


***Figure D46*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EO for condition#6.

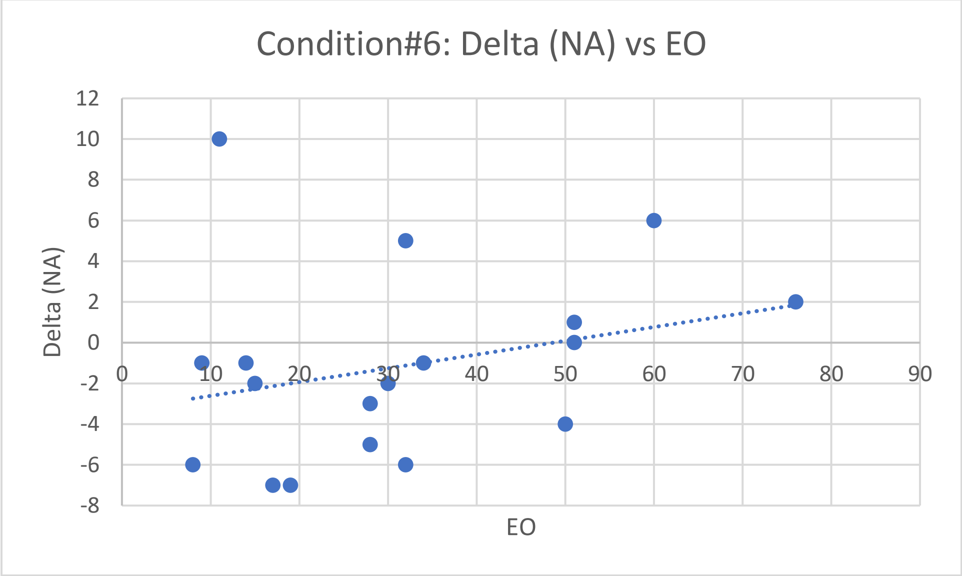
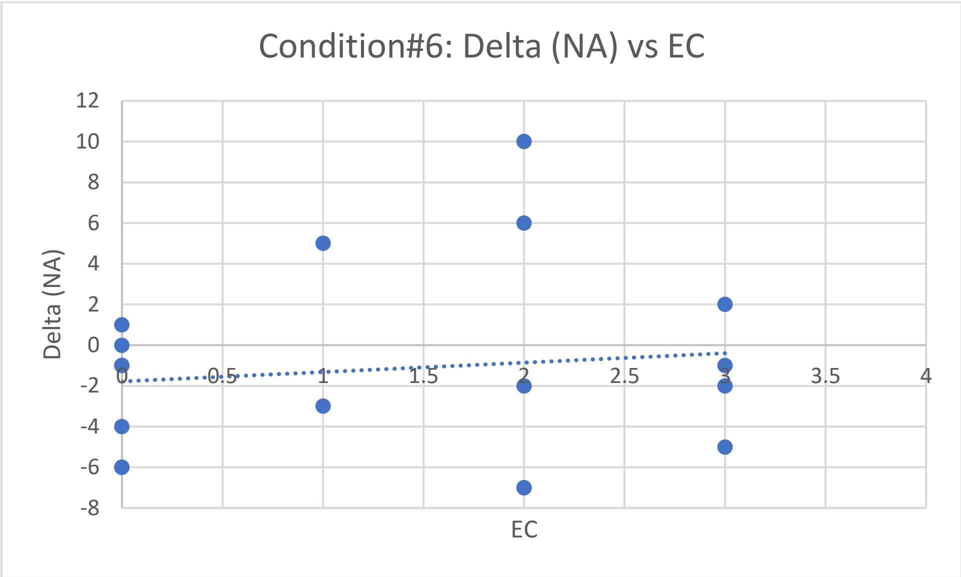


***Figure D47*:** A plot (x/y axis) shows the correlations tests variables between Delta (NA) and EC for condition#6.



Curriculum Vitae

Name: Yousif A Ali

Telephone: 96622441

Email: y4a93@live.com

EDUCATION:

• 2016: Bachelor's Degree program in Architectural Engineering from Milwaukee School of Engineering, Milwaukee, WI with a 3.65 GPA

LANGUAGES:

• Arabic (Fluent written and spoken)

• English (Fluent written and spoken)

Career:

• Architecture Engineer/Site Engineer at the Criminal Justice Department since 2017 (MPW)-present

EXTRA-CURRICULAR ACHIEVEMENTS:

• President of ASHRAE Milwaukee School of Engineering chapter in 2015

• Milwaukee School of Engineering University Ambassador in Kuwait 2015

• Certification on Engineering Program for newly employee at MPW 2018

• Certification on Ethics of the profession in Kuwait 2018

• Certification on 3D Max level 1 & 2 in Kuwait 2018

• Certification on Primavera in Kuwait 2018

• Certification on Project Management Profession level 1 in Kuwait 2018

• Certification on Project Management Profession level 2 in Kuwait 2018

• Certification on Project Management Profession level 3 in Kuwait 2018

الملخص

تهدف هذه الورقة الى دارسة تأثيرات الاضاءة والاضاءة المرتبطة بدرجة حرارة اللون (CCT) على الطالب من ناحية الانتباه والمزاج من خلال ستة حالات. من المعروف ان الاضاءه CCT العالية تؤثر على انتاجية العامل، والراحة البصرية. لذلك، من الضروري الكشف عما اذا كانت الاضاءة CCT العالية مقارنة باضاءة CCT الحالية والمنخفضة ستؤثر على انتباه الطلاب ومزاجهم بشكل ايجابي. علاوة على ذلك، تبحث هذه الورقه النقاش حول منحنى Kruithof. يتم اختبارالطلبة تحت تأثير ثلاثة إضاءات CCT (2700 K و 4600 K و 6500 K) مع مجموعتين من الإضاءة (300 lx و 600 lx) بشكل فردي. يتم اختبار المشاركين بثلاثة اختبارات ورقية. اختبار الاهتمام D2 واختبارين من جدول التأثير الإيجابي والسلبي (PANAS). تشير النتائج إلى أن ارتفاع الإضاءة يقلل من أخطاء الطلاب ويزيد من تركيز المشاركين.

جامعة الكويت

آثار درجة حرارة اللون المرتبطة وشدة الإضاءة من حيث الانتباه والمزاج للتلاميذ في الفصول الدراسية

المقدم من الطالب:

يوسف أحمد عبدالرحيم

أطروحة مقدمة لكلية الدراسات العليا لستيفاء جزء من متطلبات درجة

الماجستير في:

العمارة

إشراف الدكتور:

عبد الله حسين المحيسن

الكويت

2019