AN EXPERIMENTAL STUDY ON ON-AXIS VISUAL TASK PERFORMANCE IN THE PRESENCE OF PERIPHERAL FLICKERING GLARE SOURCE

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Submitted by,

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled "AN EXPERIMENTAL STUDY ON ON-AXIS VISUAL TASK PERFORMANCE IN THE PRESENCE OF PERIPHERAL FLICKERING GLARE SOURCE" is a bonafide work carried out by Budhaditya Ghosh under my supervision and guidance for partial fulfilment of the requirement of MASTER OF ENGINEERING IN ILLUMINATION ENGINEERING, during the academic session 2021 - 2022.

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Abstract:

Detecting an object, judging it and then taking decisions i.e. responding to that, these three things are most important while driving.

Obtaining a guideline to determine the perfect lighting condition on the road depends on many attributes as there are a lot of external factors that come into place. A number of variables including the item's visibility level, the road's shifting brightness level along its axis, and the driver's mental state in the presence of that particular lighting condition makes the object detection task highly complex and presence of any flickering glare can have a huge impact on overall task performance. And statistical data shows there is a much higher chance for an accident to occur under artificial light than daylight condition.[4]

In the past numerous laboratory and field-based studies have suggested that human reaction time is influenced by the sensitivity of the photo-receptors under a particular spectral density, age of the object, lamp type, illumination level. In this study we have tried to understand how a peripheral flickering glare source impacts on the task performance under artificial lighting arrangements.

Here In this lab experiment, the subjects/participants were asked to perform a simple visual task which is detecting an object placed in front of him and then give a response under two different types of conditions. In the first condition, there was no peripheral glare present but in the second condition two flickering peripheral glare sources were introduced. The frequencies of the flickering glare sources were changed for each trial. The same subjects took part in both types of conditions and the whole process was repeated for different CCTs of the artificial lighting. For each participant in all the lighting conditions, the reaction/response time data was recorded.

That recorded data was processed and compared to understand the general correlation between main source's CCT, flickering frequency of peripheral sources and reaction times of the observers for object recognition. It was observed that human response becomes slower and the discomfort level increases with the increase in the flicker frequency of the peripheral glare for all CCT values of the main source; and the reaction time decreases when CCT is increased. So in other terms this study confirms that there exists some amount of correlation between human reaction time, CCT of main source and frequency of the peripheral glare source.

CHAPTER-1
INTRODUCTION

1.1 Overview

When a driver is behind the wheel during the night under artificial lighting, an important task is to detect an object in his field of interest.Not only that but he has to keep an eye on the surrounding objects also and need to make a judgement of their nature and predict their movement. Based on that judgement, the driver makes decisions. A number of variables including the item's visibility level, the road's shifting brightness level along its axis, and the driver's mental state in the presence of that particular lighting condition makes the object detection task highly complex.[2][3]

This kind of a judgement process takes a lot of mental effort where his previous experiences i.e his memory comes into effect. How the brain functions while taking a complex decision like that is not much known to mankind. So more research on this domain is needed to provide a safe driving environment which will eventually reduce the number of nighttime accidents.

Though the decision making process is a gray area, one thing we can be sure of is that the whole process starts from first spotting the object. Driver needs to see the object first to make decisions. Now when we talk about seeing anything, discussion of lighting conditions comes automatically.[3] A number of variables including the item's visibility level, the road's shifting brightness level along its axis, and the driver's mental state in the presence of that particular lighting condition makes the object detection task highly complex. And apart from all these factors, the presence of any kind of glare plays a major role.

In simple terms we can say that glare is an effect of light that reduces the efficiency of visual performance. When a bright light is present in our viewing field it is our natural reflex to protect our eye by blinking or looking away or temporarily shielding it by reducing the pupil size so that less amount of beam can enter, if this happens the presence of glare is confirmed.

It has also been seen that the amount of time present in a low light condition influences the effect of glare on a subject's visual performance.[5]

In a real life situation like on the road at night, car drivers spend most of their time in low surrounding light conditions where glare can have a much more fatal effect.

Among the eight types of glares given by Voss(1999)[1] we have used one type of glare which is a discomfort flickering glare where the source of the glare is present in the peripheral viewing field and the task is being performed on on-axis viewing field. In real life this kind of glare source can be roadside billboards, faulty lights in the roadside shops etc.

We can call a glare discomfort glare if it causes a psychological sensation but not necessarily blocks the eyes from getting information. It has been shown that the effect of discomfort glare increases when we increase the task complexity.[6]

But still there is a confusion in the academic domain if discomfort glare affects the decision making of a human being. This study can be a step to find out more about that.

There are two main parameters, on which this current study stands. They are -

1. Reaction Time:

The interval between the display of visual or auditory stimuli and a distinct response that is generated by the stimuli and provided via a response key is known as reaction time or response time. That implies it is the time needed to recognize the stimulus, choose a specific action, and start the action by employing a specific set of muscles[7]. RT is related to a person's capacity for quick decision-making [8]. The RT of a driver should be low when driving at night, which calls for the driver to spot obstacles quickly and take appropriate action when necessary. According to a study, ambient illumination and contrast have a significant impact on response speed[8]. Additionally, it relies on the age, mental health, neurological health, visual health, and muscle performance of the driver.

2. CCT:

A single distinct value called the colour temperature is typically used to describe the colour of a light source. "The temperature of a Planckian radiator whose radiation has the same chromaticity as the given stimulus," is how the CIE(1987)[10] defined colour temperature. This implies that the black body's colour appearance at that temperature with that of the test source should be Identical. However, the CIE did not specify the level at which chromaticity should be "identical," thus colour temperature evolved into a broader perspective on the idea. So, Correlated Colour Temperature (CCT) is used to assess the relative measurement of light sources' coloru[10]. "The temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing condition" is how CCT is defined (CIE, 1986)[11] and CIE 1960(u,v)[12] diagram is used to determine the chromaticity coordinate of the nearest black-body radiation for a certain light source for measuring CCT.

1.2 Aim of the study:

There are not many results available to conclude how a peripheral flickering glare affects the object detection and the human response. In This study the human response or performance has been quantified here as reaction time as they are proportional in relation. In this study participants are subjected to a peripheral flickering glare source inside the laboratory and the Behavioral performance is measured while the ambient CCT is varied. Aim of this study is to observe how the peripheral flickering glare influences the Behavioral performance of a human being under artificial light of different CCT. In other terms this study has tried to investigate if there exists any certain amount of correlation between flickering frequency of the peripheral glare and reaction time of the human observers and the CCT of the main light source.

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CHAPTER-2
HUMAN AND LIGHTING

2.1 Human Vision:

2.1.a The eye

Eyes are one of the most sensitive organs in our body to respond to light and responsible for our visual functions. When light passes the clear frontal layer of the eye known as convex shaped cornea it excites various photoreceptors. Now the signals from different types of photoreceptors trigger different brain functions and Vision is one of them.

After cornea, there is a small opening which is called pupil that allows a controlled amount of light to go inside, colored part around pupil, the irish controls the opening.

Then there comes a auto adjusting clear convex lens, and a refractive vitreous fluid medium.

Cornea, lens and vitreous fluid work together to focus the light rays at a particular position on the retina(light sensitive tissue at the back of the eye) where special photoreceptor cells responsible for vision exist. They turn the light signal into neural signals and are carried via optical nerves. Our brain processes those signals and that's how an image is formed in our brain that we see.[1]

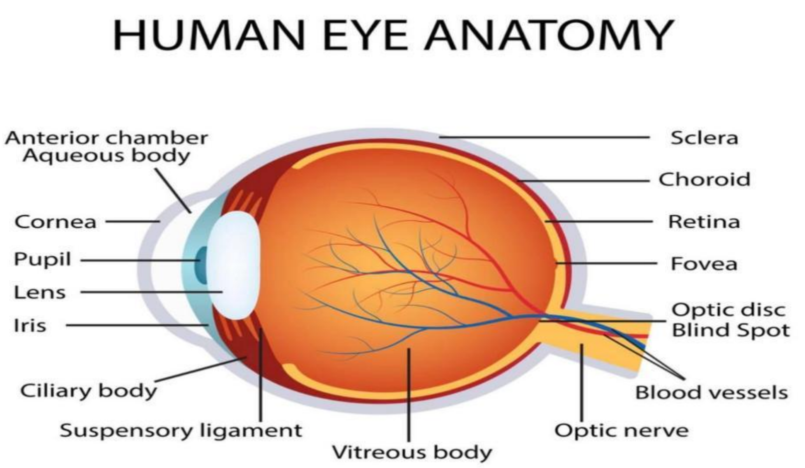

Fig - 1[2] [Source : eyesafe.com]

There are two types of photoreceptors that are mostly. responsible for our vision,

i. Rod: These cells are in charge of seeing in dimly lit environments (scotopic vision). They have poor spatial acuity and are extremely bad in terms of colour vision.
ii. Cones: Cones are responsible for excellent spatial acuity and are active at higher light levels (photopic vision). They are the reason we can see colours.

Mostly cones may be found in the central fovea. Cone cells are of three types, Short-wavelength(blue) sensitive cones, middle-wavelength(green) sensitive cones, and long-wavelength(red) sensitive cones—abbreviated S-cone, M-cone, and L-cone respectively.[2]

From the fovea the density of the rod cones starts to fall, it has a drastic fall at 10° - 15° then the density of rod cells start falling at a constant level. At 15 - 20 degree from fovea the level of cone cells reaches its peak and at the blind spot where the optic nerves meet the retina there is no photoreceptor present that is why no image can be formed at that point.

2.1.b Central and Peripheral vision:

If a human stands staring looking forward, the area he can see without rotating his head can be called his field of view or it is the "spatial array of visual sensations available to observation in introspectionist psychological experiments"[3]. The human visual field has a range of 100-110° from centre fixation, of which it is divided into two parts “Central of fovea” and “Peripheral Vision”.

For the Central version, it expands 5 degrees from the central fixation and the rest of the visual field is known as Peripheral Vision. The peripheral zone can further be broken down into three categories: "Far peripheral" vision, which refers to the area at the edges of the visual field; "mid-peripheral" vision, which makes reference to medium eccentricities; and "near peripheral," also known as "para-central" vision, which is located next to the centre of stare.

The Image is attached below to show the different central and peripheral visions:

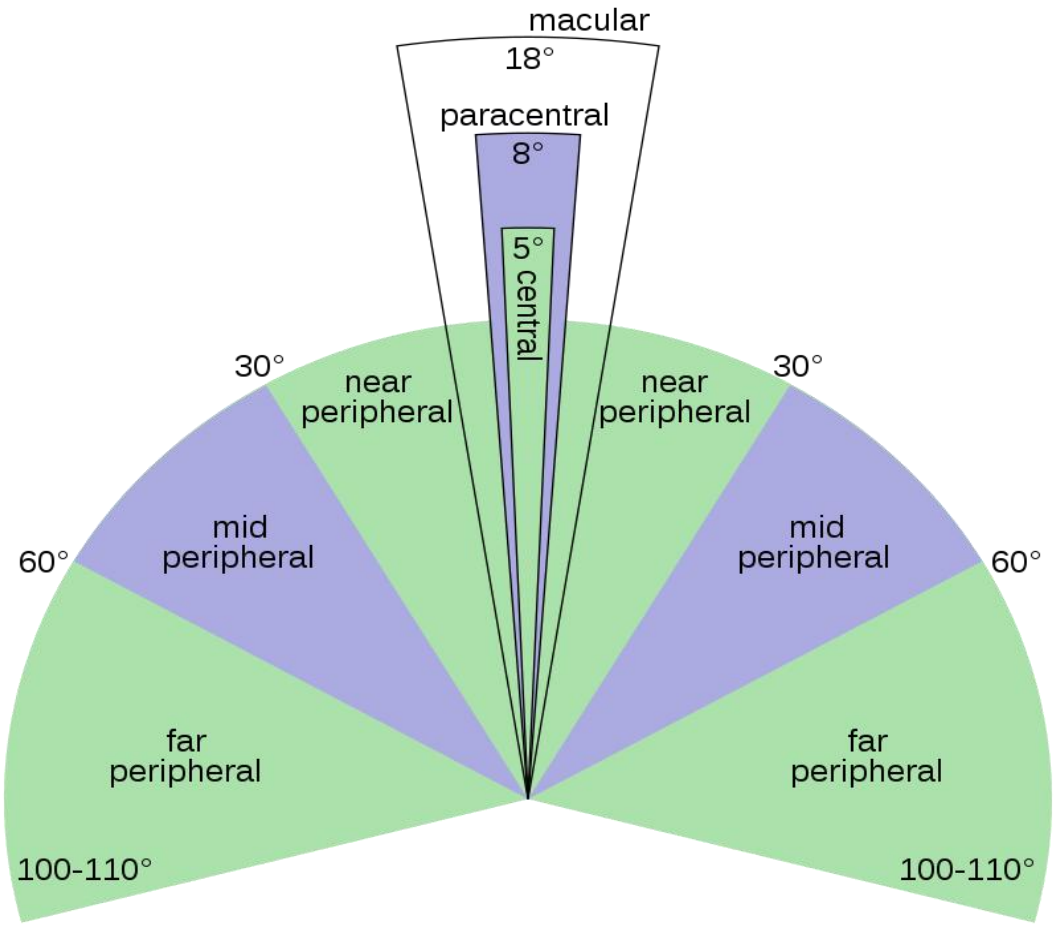

Fig-2[4] [Source: Wikipedia]

2.1.c Photopic, Scotopic and Mesopic vision:.

Human eye is an absolute genius in handling a humongous number of light levels. It can be exposed from bright daylight to starlight and in every case it gives the best visual experience even though there are limitations of individual neurons of our visual system.

Achieving sensitivity adjustment over such a wide range is not an easy task. So to work properly both types of the visual photoreceptor cells rod and cone need to work together and because of that sometimes colour rendering and spatial acuity is compromised.

Sensitive rods operate at lesser light intensities i.e. scotopic levels, the less-sensitive cones which get activated at a higher light intensities i.e. photopic level, and when their ranges overlap they work together at mesopic level.

Surprisingly though colourful dynamic vision comes from the activity of cone cells but they are roughly 5% of the number of rod cells present. And almost all the cone cells are densely packed inside the small fovea region. And except for fovea everywhere inside the eye rod cells dominate the cone cells. So our eyes have been adapted in such a way that it adjusts the flow of light inside our eye to be suitable for the cones to react and the optic lens tries to focus the light on the fovea.[5]

But In contrast with the cones, rods are optimised for scotopic and lower mesopic regions. Rods are slow to respond but very sensitive to light that means they can trace one single photon and have a longer exposure time so that photons get integrated and form a better image at low light.

Though our eyes have a great adaptive power to various lighting conditions that doesn't mean we should be exposed to any lighting condition for any task. The main purpose of the lighting design guidelines are to provide the most comfortable visual atmosphere for a particular task.

Now for that it is needed to take a quantitative approach in order to express the visual impressions that a particular lighting evokes in humans when lighting is designed, specified, installed, and maintained. Photometry is the technique used to measure light in this manner.

A Photometric method which is based on the spectral luminous efficiency function V(λ) proposed by CIE (Commission Internationale de l'Éclairage has proposed) standard photometric observer is being used everywhere so far.

The graphical representation of V(λ) tells how our visual perception changes with the wavelength of the incoming photons while keeping the power fixed.

In the given figure V(λ), the X-axis represents the Wavelength and the Y-axis represents the qualified visual perception.

The plot of V(λ) has been done by studying the spectral sensitivity at the centre of the field of view by using small stimuli subtending angles of 2° or 3°. Now for that small field of view mostly the image forms at fovea, which is highly populated with the cone cells exclusively and that is why we can roughly say the spectral sensitivity of the cone cells is what is represented by the V(λ) curve.
And we represent the scotopic spectral luminous efficiency function as the V'(λ) curve.

Now In the case of mesopic regions the whole thing becomes extremely complex as they depend on signals from both rod and cones. These two types of photoreceptors not only have a different spectral luminance sensitivity but their pathways through which they send their signal are also different. That is why standardising mesopic spectral luminous sensitivity is very difficult.

According to CIE 191, there are a number of mesopic spectral luminous efficiency functions from which one should be selected based on the adaptation. The adaptation state for a lighting scene must be identified in order to determine which function should be used in the scene.

In **figure-3**, the first graph shows how an image is formed in the photopic region. L, M and S cones are represented with red, green and blue lines respectively. And the overall V(λ) graph is represented by a dark black line. Here Rod cones are not active and the light is focused at fovea.

In the next graph, it is the mesopic region. Here rod and cones both contribute to form an image. V'(λ) curve of the scotopic vision is plotted in a grey line. We can see the overlap between the V(λ) and the V'(λ) and the respective image formed is shown.

In the 3rd graph of **Fig - 3**, we can see only the rods are active. And as expected, the respective image formed is colourless.

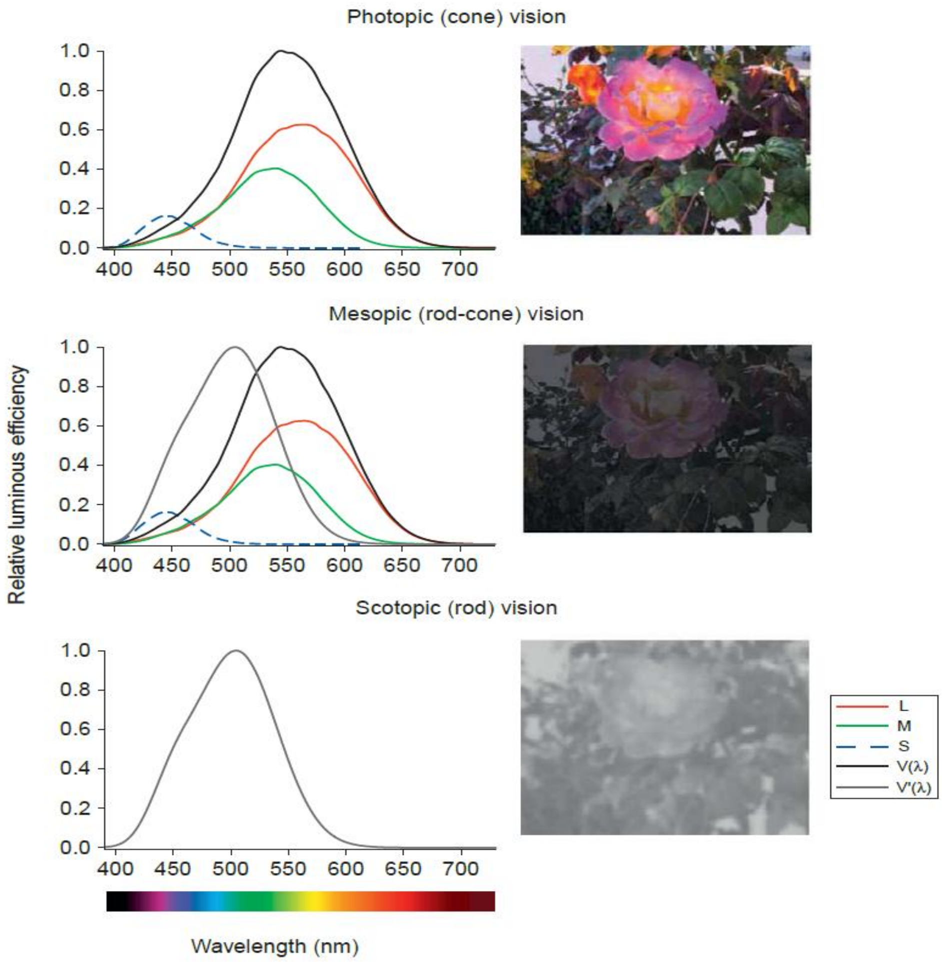

Fig - 3 [5]

2.2 Non Visual Responses and Human Centric Lighting

The seemingly paradoxical term human centric lighting is becoming more popular these days. This term may seem paradoxical because all kinds of artificial lighting was supposed to be for humans. But in Illumination science the term human centric lighting means a lighting scheme that considers both the visual and non visual effects. Now it is known that light when enters through our eyes it triggers a wide range of potential effects such as visual performance and comfort, as well as sleep quality, alertness, mood, and behaviour with implications for human health, learning, and spending.[6]

Now while talking about the non visual and non image forming(NIF) responses the question arises what are these responses and from where it comes. For starters, light is the primary stimulus for our biological clock to operate properly. Sleep wake cycle is reset by light every morning and the SCN (suprachiasmatic nucleus) which is responsible for circadian rhythm is stimulated.[7]

The term "ipRGC-influenced light responses" (IIL responses) was used by CIE[8] to include the light-induced reactions produced by ipRGCs. These ipRGC cells are the intrinsic photosensitive rational ganglion cells that are categorised as the class three photoreceptors. Being different from the other ganglion cells these cells contain a light sensitive protein called melanopsin because of which the ipRGCs are also called the melanopsin-containing retinal ganglion cells.[9][10]

Melanopsin is different from rhodopsin (present in rod) and photopsin(present in cones) as these proteins can't generate visual signals. There are nearly three types of ipGRCs all of them have a distinct response to the light and target at the brain.[11]

While sending signals to the brain these ipRGC neurons mix the extrinsic signals from the rod and cone cells with its own intrinsic signals(produced by melanopsin).[12] So while saying ipGRC signals we need to consider both the intrinsic signals and extrinsic signals.

Also though the term adopted by CIE ipRGC-influenced light responses to encompass the non visual responses it'll be wrong to understand it as only the ipGRCs are responsible for all types of non visual responses. Rather all types of photoreceptors are involved in producing non visual responses.

Terms circadian, neuroendocrine, and NeuroBehavioral, adopted by IES in 2008[13] sit perfectly to explain all the types of Non visual response stimulated by light.

Circadian responses are a group of physiological processes that takes place on an approximately 24-hour cycle, including the sleep-wake cycle. The brain's regulation of hormones is known as a *neuroendocrine response*. And the connection between a person's behaviour and how their neurological system functions is known as a *neuro behavioral response*. Signals generated from the rods, cones, and ipRGCs(mixture of both the intrinsic and extrinsic signal) , can affect all of these responses.[7]

Image given below gives a pictorial representation of how Light produces human responses. Here light radiation passing through our eyes, on or through the skin is not considered.

At the top row the stimulus and the responses are drawn. At the top. Temporal pattern denotes the timing and exposure time pattern, three dimensional distribution of the light field referred as spatial power distribution, light level means the quantity or amount of light in radiometric or photometric unit and the SPD i.e. spectral power distribution that deals the colour is given as Light spectrum.

Combining these four factors we get the light stimulus.

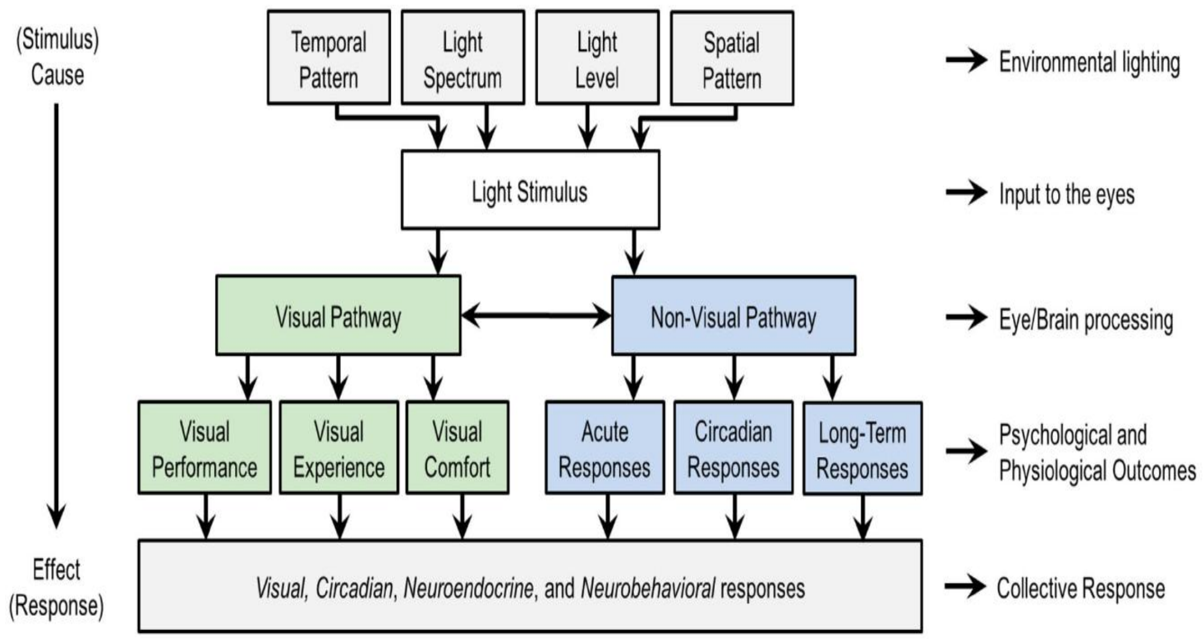

Fig: 4[14]

2.3 Brain Wave distribution:

The primary region which is responsible for receiving, integrating and processing the visual data that comes from the retina. In the back of the brain inside the occipital lobe of primary cerebral cortex, visual cortex is located. Visual signals after getting generated form the retina when travelling towards the visual cortex they pass through the nucleus called lateral geniculate as seen in the **Figure-5**. A visual cortex is present in both the left and right hemispheres of the brain; the left hemisphere's visual cortex gets signals from the right visual field, while the right hemisphere's visual cortex receives signals from the left visual field.

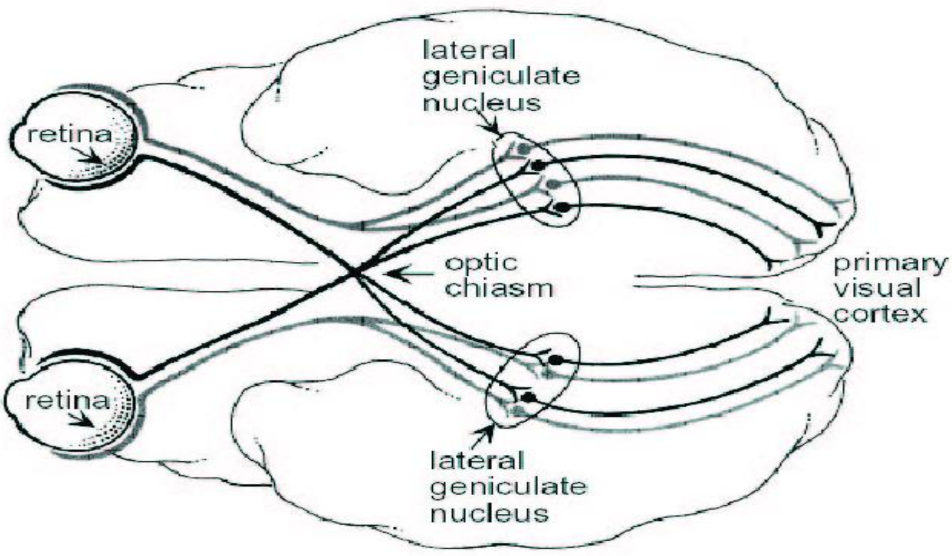

Fig - 5[17]

Neurons are the fundamental components of the visual cortex and the brain. Electrical charges are the primary means through which neurons interact. With the assistance of an electroencephalogram, one may observe these electrical changes as brain waves (EEG). Through electrodes affixed to the subject's scalp, an EEG equipment captures electrical signals from the brain, especially postsynaptic potentials of neurons coming from the cerebral cortex.

The EEG monitor receives the electrical impulses generated by the brain from the electrodes. EEG not only measures the signals but also amplifies them as the electrical signals coming from the brain are extremely low voltage in the range of 10s of microvolt. So generally EEG amplifies them by ten thousand times for us to understand.

After several studies scientists have identified several brain waves, and these waves are categorised mainly into 5 types based on their frequencies. The frequency increases with the increase of brain activity. In terms of increasing order of frequency the categories are Delta, Theta, Alpha, Beta and Gamma.[18] The **Table -1** below summarises the importance of each brain wave in simple terms

Brain Wave	Frequency range	Important Features
Delta	0.5-8 Hz	*Key Feature: Cure, sleep very well.* This wave has the lowest frequency of all. It denotes minimal brain activity. Delta is most prominent when someone is in deep sleep or in a state where he has no external awareness for example meditation. Delta is also associated with empathy and intuition.
Theta	3-8 Hz	*Key Feature: Deep relaxation, meditation, Improved Memory* Theta signals dominate when we dream in light sleep many times it is called having a dream consciously. Also during meditation Theta signals are produced. It is also associated with stress relief and memory relocation.
Alpha	8-12 Hz	*Key feature: Creativity, Relaxation, Visualisation* Alpha signals are associated with overall body and mental coordination, calmness, alertness. It is said that this signal denotes the best condition for reflex and problem solving and visualisation when we are learning or doing something creative.
Beta	12-38 Hz (Beta 1: 12-15 Hz, Beta 2: 15-22 Hz, Beta 3: 22-38 Hz)	*Key feature: Beingware, Concentration.* Denotes a state of high consciousness and alertness and focus towards a cognitive task in decision making or judgement or producing new ideas. It is beneficial for productivity for the tasks that require a higher level of brain engagement and concentration.
Gamma	38-42 Hz	Fastest of brain waves, Highly prominent when expanded consciousness and spiritual emergence, altruism.

Table - 1

2.4 Benefits of Human Centric LIghting:

As per CIE and IES Light is defined as the optical radiation between 400 and 700nm. This defination treats light as a stimulus that is capable of producing any type of visual or non visual responses. But in contrast to that when we talk about lighting, that means employing light to create a visual environment based on theory, science and method to get a desired outcome. That will not only satisfy the visual demand but also incorporate human factors like 1. circadian rhythm. Others include 2. mood 3. visual acuity. 4) Sensation 5) Sustainability and energy efficiency 6) Performance and Productivity. One may assume that in the near future, other factors will be added to the list already provided.

CIE has adopted the word *integrative lighting* to describe the lighting schemes that include these human factors.[15]

Now to sum up, benefits of incorporating the human factors in lighting has three major aspects, These are:

1) Visual Benefits : good visibility, visual comfort, safety
2) Biological Benefits : alertness, concentration, deep and stable sleep-wake cycle, cognitive performance
3) Emotional Benefits : improved mood, relaxation, impulse control.[16]

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CHAPTER-3
BACKGROUND OF THE STUDY

3.1 Importance of the Work and Previous Studies

All lighting designers are quite concerned about motorised roads. Nowadays, the word "visibility" is used universally to describe how well a road lighting scheme works. A decent road lighting system must provide clear sight. As a result, the study on visibility-based road illumination is now quite well-known. The road surface and its surrounds might be illuminated today to improve visibility and protect any objectives that the driver can see.[1]

To provide maximum safety and comfort for the drivers at the night when the traffic is at its peak quality road lighting is required. In such cases drivers need to identify an object in any part of the road as fast as possible and take decisions accordingly without difficulty. Also a good road lighting scheme should take consideration of the other slow moving objects like pedestrians and cyclists.[2][3]

Also the road lighting scheme should be in such a way that it helps the driver to detect objects if there are glares from the car headlights coming from opposite directions or any other sources. Another very important thing to consider is that objects may not always be on the road, there can be objects located beside the road. A driver needs to spot that, judge its future movement and take precautions accordingly.[4] So not only the light level but ability to perform a task under a particular lighting condition should be considered also.

So human hour spent on research on artificial road lighting is very justifiable as in return it'll improve the overall safety in the night that will eventually lead to decline in accident rates.

In normal practice with the change in road type the photometric parameters of a quality Road lighting changes accordingly. The road lighting illuminance level is mostly 1 - 2 cd/m^2 in the urban area and in rural areas is in the range of 0.1 to 1 cd/m^2.

At the same time it is very unfortunate that the periphery of the roads is not taken care of most of the time in both urban and rural areas and the avg luminance level is extremely low. And needless to say, it is extremely important as various potential hazards come from there, also any kind of glare coming from the completely dark periphery may cause difficulty on on-axis object detection also.

3.1.a Mesopic vision and Road Lighting:

The eye's sensitivity shifts from photopic to scotopic and vice versa during the intermediate vision between photopic and scotopic. Thus making the vision at night a major problem. In particular, while driving at night it falls into a zone where the average road surface brightness level is neither in the photopic range nor in the scotopic range hence Mesopic vision comes into picture. As a result Mesopic vision has received attention in research work on night time driving.[1][2] The luminances of mesopic light range from around 0.001 to 3 cd/m2. Further research has shown that the user's cone and rod receptors are both engaged while driving at night. Therefore, it may be claimed that both rods and cones are activating in a mesopic situation. Now if we take the non visual psychological responses of ipRGC the decision making process becomes more complex. [5]

Now it is known that in case of mesopic vision both rod and cone have to work together II and both have some degree of contribution to form the visual image. Not the degree of contribution is not the same for all the cases it varies with different values of average Road surface luminance. Now the average luminance value varies a lot, from low mesopic level it can go to high photopic values. Even on the same road surface it may vary drastically so our vision needs to be a very dynamic one and that makes the object detection more complex of a task.

Apart from the luminance level there is an another aspect to consider mesopic vision while designing road lighting is that, as per the human eye anatomy cone photoreceptors are densely packed in the foveal region, everywhere else its presence is significantly low and and everywhere on the retina, except fovea, rod cells outnumber cones with a great margin. So fovea is mostly responsible for our photopic vision. But while driving, non-foveal vision or peripheral vision is needed too because objects or distractions may not always come from the on-axis zone. In these types of vision the image is formed on the other parts of the rairna where both rod and cone cells are present in different ratios which points toward a mesopic vision.[6]

3.1.b Foveal and peripheral tasks:

So there is no doubt that while driving the driver has two types of task: i. On axis object detection or the foveal task and ii. Perception of the peripheral task.

i. On-axis or foveal object detection task:

The focus of this job is only on the identification of objects that are in front of the driver, and it is independent of brightness. The fovea, which is in charge of performing this function in the human eye, is situated in the centre of the retina, where vision is the sharpest. Since the fovea only contains cones, photopic vision is the only sense that can aid in activities involving direct object detection.

ii. Peripheral Task:

This job affects how bright light is seen over a wide region and how safe we feel in it, both of which are related to human eye perception. The entire retina's rod and cone photoreceptors work together to perceive spatial brightness, which involves both scotopic and photopic vision. Cones and rods both have a role in mesopic vision. Therefore, it is essential to research how peripheral tasks affect the ability to identify objects with the eyes focused, or more specifically, how the two views interact.

3.1.c Previous Studies

Numerous laboratory and field-based research projects have been carried out to determine how well humans perform for a visual job under specific illumination conditions. The overarching goal of the majority of these studies is to examine how task and lighting conditions influence task performance, which is heavily reliant on vision. The following list includes some of the most important scientific articles.

Peter R. Boyce provided a conceptual framework of three main pathways by which lighting might impact human performance in his study on "Human Factors in Lighting"[2]. These are achieved through the interaction of visual performance with motor and cognitive function, mood and task-related motivation, and the circadian timing system. The entire structure is represented in **Figure - 6**:

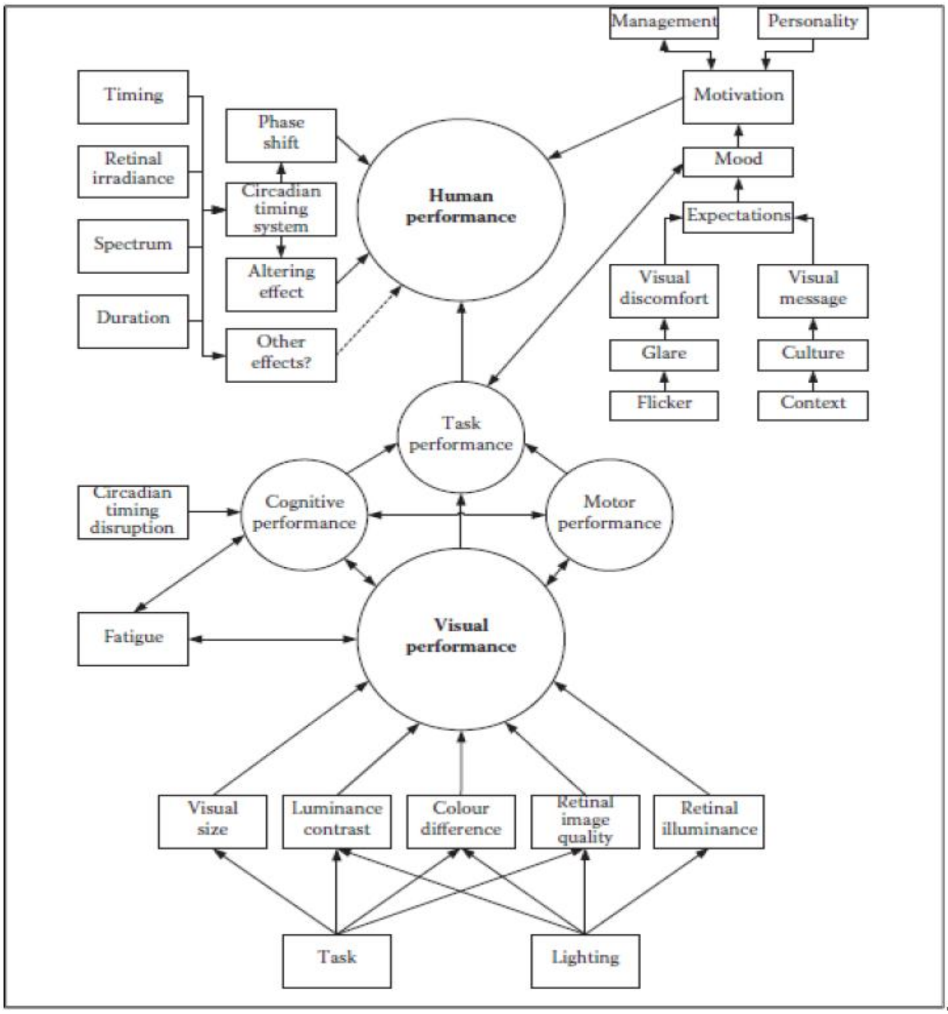

Fig - 6
[A theoretical framework outlining the three ways that lighting conditions might affect how well people perform. The diagram's arrows show the direction of the influence.]

In their study "Simulated driving performance and peripheral detection at mesopic and low photopic light levels(2000)" Bullough and Rea worked to show how human responses in object detection changes with change in SPD and luminance level. In their experiment they used 4 different luminance levels from 0.1 cd/m2 to 3 cd/m2 and the 4 types of SPDs including MH and HPS lamps with s/p(scotopic/photopic) ratios from 0.63 to 3.77. That study concluded that there was not much effect of SPD on foveal object detection but performance improved significantly with increase in luminance level. But in case of peripheral task it was highly dependent on both SPD and luminance level.[4]

The extensive study conducted by the past researchers is summarised below in two sub-categories as a result of a thorough review of their prior efforts in the field:

1. Prior work on calculating visibility;
2. Prior work on object detection.

1. **Prior work on visibility Calculation:**

The visibility of the thing under a certain lighting situation affects how an object is seen, or more particularly, how it is detected. Although the name "Visibility" refers to a relatively broad field in lighting engineering, its principles may be expressed mathematically as the "contrast sensitivity function," which is a function of the visual system (this model, of course, excludes physiological processes in the eye and brain).

This "contrast sensitivity function" (*p*) is dependent on background luminance (l_b) (cd/m²), the luminance difference between the object and background (Δl) (cd/m²), the size of the object (α) (minutes), and observation time (t sec), according to Frederiksen at el's technical report no. 17, "Calculation of Visibility in Road Lighting".[13]

The relationship is: $p = f(L_b, \Delta l, \alpha, t);$

Where "p" is the probability of detection of an object.

Later, a number of academics sought to determine the most precise visibility level calculation model, and Adrian's visibility model[14] is thought to be the best choice. The Illuminating Engineering Society of North America eventually updated Adrian's model and released it as "ANSI/IESNA RP-8-00."

In this model the factors which affects visibility are:

1. Adaptation Level – Relative contrast Sensitivity
2. Disability Glare
3. Contrast
4. Size
5. Time of viewing
6. Transient Adaptation
7. Observer Age

As a result, it is well accepted on a global scale that glare affects visibility. Disability glare is connected to veiling luminance, which is brought on by dispersed light from bright sources that enter viewers' eyes and lessen the retinal luminance contrast. The following table summarises the foregoing overview of the prior research on calculating visibility level:

Sl. no	Publication	Author	Name/Description
1	CIE 19/2, 1980	Blackwell	"An Analytic Model for Describing the Influence of Lighting Parameters Upon Visual Performance"
2	Report No. 17, Lysteknisk Laboratorium, Denmark	E. Frederiken, N. Rotne	"Calculation of Visibility in Road Lighting"
3	ANSI/IESNA ANSI/IESNA RP-8-00	Werner Adrian	Visibility model based on: • 60-year-old moving observer • 8 cm, 50 % reflectance target viewed at a height of 1.45 m and 83 m distance (1-degree downward angle) • 0.2 second viewing time • Visibility Model accounts for eye adaptation, target/background contrast and glare from the luminaires

Table - 2

This research work focuses on the influence of peripheral flickering glare source on driver's performance in conditions like street lighting.

2. **Prior Work on Object Detection:**

Numerous research studies have been done in the field of target detection at mesopic light levels in a driving context. Of which, the most relevant experiments are described here. In most of the experiment the target was presented in the periphery of the 2-degree visual field.

In the study conducted by Akashi, Yukio, M. S. Rea, and John D. Bullough (2007)[9] a field research was done to determine how different light sources, including metal halide and high pressure sodium vapour affected how fast drivers could react in a real-world driving situation. The study's participants had to drive a car for two different lighting installations while also determining the direction of an off-axis target (i.e. towards or away from the street). Following that, the driver of the car must accelerate or brake as necessary. The study found that metal halide lighting improved peripheral sight and that uniform brightness distribution in lighting installations speeds up response time.[9]

In the study "A Mesopic Vision Approach for a Better Design of Road Lighting(2004)" by Bisketzis, N., G. Polymeropoulos, and F. V. Topalis[7] disagreed with the previous study by Bullough and Rea[4]. Using brightness matching and reaction time they concluded MH lamps are always superior to HSP lamps in both on and off axis object detection.

In "Age differences in visual abilities in nighttime driving field conditions(1996)"[8] Chrysler, Susan T., Suzanne M. Danielson, and Virginia M. Kirby tried to find the effect of age of the drivers in terms of response using reaction time. Subjects were asked to perform several tasks like Landolt ring legibility task, small object and pedestrian detection task. That experiment also included the performance under bad weather conditions and in the presence of oncoming headlamp glare source. It was found that in all the tasks performance was reduced by 20 - 40% in the older group. In the reduced visibility condition performance dropped by almost 51% for both the groups and 37% avg drop in the presence of headlamp glare.

Another similar research was conducted by Barrett et al.(2014)[10], where an object detection task was carried out using a different glare installation. It was discovered that veiling brightness significantly affects the observer's performance.

In Another lab based experiment based study Sivak, Michael, et al(1989)[11] it was tried to find out if the effect of on axis glare depends on the task which is supposed to be performed with changing glare luminance or not. In that experiment subjects were asked to spot if a gap had appeared, and were asked to rate overall discomfort. It was found that the smaller the gap was to detect discomfort was increased and the overall discomfort rating followed. So the study concluded difficulty if the task increases the effect of glare.

In a breakthrough study J. F. Schouten and L. S. Ornstein(1939)[12], showed that due to the presence of peripheral glare perception the brightness changes. In that study a method was proposed to quantify the change in perception. In that experiment the viewing area of both eyes was separated using some vails so that two eyes saw two different surfaces, one eye of the observer was exposed to the glare and another eye had no glare. After a brief exposure of peripheral glare, now the illuminance of one surface was changed till the observer responded as an exact match. That study also found that the rate of recovery was highly dependent on the time of exposure.

3.2 Problem Formulation:

One of the main visual artefacts that drivers face in road scenario, is flicker based stroboscopic effects or phantom array effects[15]. CIE states that any change in light level or spectral distribution of light that can be measured, is called temporal light modulation or TLM and visual perceptions of these modulations of human being is called temporal light artefacts or TLA[16] . The normal frequency range of flicker from from just few Hz to 80 Hz. Flicker can be caused by mains voltage fluctuations, product characteristics, or system-level interactions like an external dimmer that is not compatible[17]. It has been observed that in situations like night time driving scenarios, automobile headlamps or street lights, high power lights from the roadside shops etc. can act as glare sources. In most instances glare effect of these sources comes from the peripheral region these sources can have flickering. Another major source of of flickering peripheral glare can be road side electronic bill boards. They are being installed everywhere these days.

Few publications exist that discuss how this type of danger (peripheral flicker) affects drivers. Peripheral flickering limits or similar standards or considerations are likewise remarkably lacking. This lab-based experiment is being conducted to assess how drivers' response times are affected by peripheral flicker of four flickering frequencies at three levels of CCTs from the primary source. The level of a driver's cognitive function, as well as numerous behavioural variables, may be inferred from the measurement of response time or reaction time. These factors are crucial for creating a lighting design that is both driver- and human-friendly.

3.3 Original Contribution by the author:

The original contribution of this thesis work by the author are as follows:

1. The design of the experiment along with stimulus preparation.
2. Analysis of the behavioural data to investigate the influence of peripheral flickering glare on on-axis task performance.

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CHAPTER-4
EXPERIMENT AND EXPERIMENTATION

4.1 Experimental setup and Method

Real-task studies cover the task of determining human performance under a particular kind of lighting. Real-task studies, as opposed to abstract studies, require that participants complete a particular task in order to quantify their performance under different control conditions. In these investigations, measurements are done either using a genuine task performed in the field or with a lab-based simulation of the task. Real-task studies are unique in that they achieve high levels of face validity. The measured value derived from these studies gives specific visual, cognitive, and Behavioral results since face validity is the attribute for a given lighting condition of a specific task, hence these studies do not provide a generalised model.

On the other hand, abstract research has a high value for generality and a low value for face validity. These experiments are excellent for determining the generalised outcome for a straightforward visual task where the lighting situation has no particular bearing on cognitive or motor responses. Predictive modelling uses these types of studies.

This study project calls for the performance of humans doing an item detection task in the presence of a peripheral flickering glare source. Consequently, this research project is a kind of real-task study. For this particular road illumination scenario, the experiment has been particularly constructed to find the reaction/response time data, i.e. Behavioral data.

In the Table below the differences of these two kind of studies are listed side by side

Experimental study for different lighting condition

Real-Task Study	Abstract Study
1. Involves a specific task, perfomed by participants (FaceValidity - High, Generality - Low) 2. Different control condition can be changed easily 3. Involves cognitive and behavioural response of the specific lighting condition. Example - Present research work	1. Generalised task, (FaceValidity - Low, Generality - High) 2. Cognitive and motor responses are minimally influenced by the lighting condition 3. Mostly used for predictive modelling Example- Road-class classification problem by gathering sample data and generalised the result to find the road class.

Table - 3

4.1.a Approach

The purpose of this Experimental work is to determine how a peripheral glare source affects a person's ability to execute an object detection task. The word "human performance" in the context of task performance refers to seeing an object placed in front of the subject and responding to that, which includes visual, motor, and cognitive abilities. The output was taken as a Behavioral data.

The controlled lighting environment is necessary for the object detection task in the required lighting condition. Because the face validity of the current study work is high, the entire experiment has been carried out in a simulated setting. It is true that real-world factors like temperature change, rain, sound noise etc. affects human performances to some degree but it is not possible to accurately replicate them in the laboratory environment. Fortunately their effect is very minimal in this context that is why this simulated setup with controlled lighting conditions produced a satisfactory result.

Depending on the Lighting conditions the experiment can be divided majorly into two types of trials. One where there was no peripheral flickering glare was present and another was in the presence of peripheral flickering glare source. Now the trial where flicking glare was present can be divided into four sub trials depending on the frequencies of the flicker. Now for each flicking glare conditions and no-glare condition CCT of the main light source was varied. The Behavioral data was taken using a custom made stopwatch operated by the participant in the time of each trial for each participant.

4.1.b Experimental Setup

Though the aim of this study is to reach a conclusion about the responses made in driving situations, the experiments were performed inside the laboratory of Illumination Engineering section, Electrical Engineering Department, Jadavpur University. The lighting setup and the surfaces were made to match the night time road lighting condition as appropriate as possible. The indoor walls of the laboratory, furniture and other equipment present were either painted in pitch black in colour or covered in black sheets to eradicate the reflection of the light and mimic a dark surrounding. All the windows and other openings were covered tightly so that no outside light could enter the experiment premise.

The experimental setup had four major components.

1. **Light Sources** : There are 3 LEDs in total. One of them was a smart LED controlled by an android application that was used as the main source (12 Watt) and two other LEDs were used to produce the peripheral flickering glare (9 watt each).
2. **Custom made flicking frequency controller**: This is an Arduino Uno based controller developed by the researcher. This was used to change the flickering frequencies of the glare sources.

3. **Objects**: As the name suggests these were used as objects. It was a yellow coloured cube with dimensions of 8cm × 8cm × 8cm.
4. **Reaction Time measuring Device**: This is also an Aurdnio uno based device which was used to measure the reaction time. This device was coupled and synchronised with a programmed active shutter glass. Two push buttons were present in the device, one to start the counting and another to record the reaction time.

Details about these components are discussed later.

Now using those components the experiment's location has been prepared. The main 12 watt LED source was mounted on a street light pole at a height of 2 m from the ground and the other two LEDs were placed a height of 1.5m above the ground and next to the subject. These two LEDs that acted as a peripheral glare source were positioned 15° apart from the horizontal axis. Which was parallel to the "A" row of the Grids.(Figure 8)
Now as specified in CIE 140 - 2000, 25 evenly placed grid points were drawn that had 5 rows (A to E) and 5 columns (1 to 5) as shown in Figure 8. Every Grid point was separated by 0.5m from its sidewise adjacent grid point.

The main source or main pole is maintained so that its nadir point is on "E1." Below is a detailed illustration of the grid points that are used and are circled in the image. The observer is situated on the extended straight line that connects all the locations on column 3 and is 15 meters away from grid point "E3." In Fig. 8, a thorough pictorial description is provided.

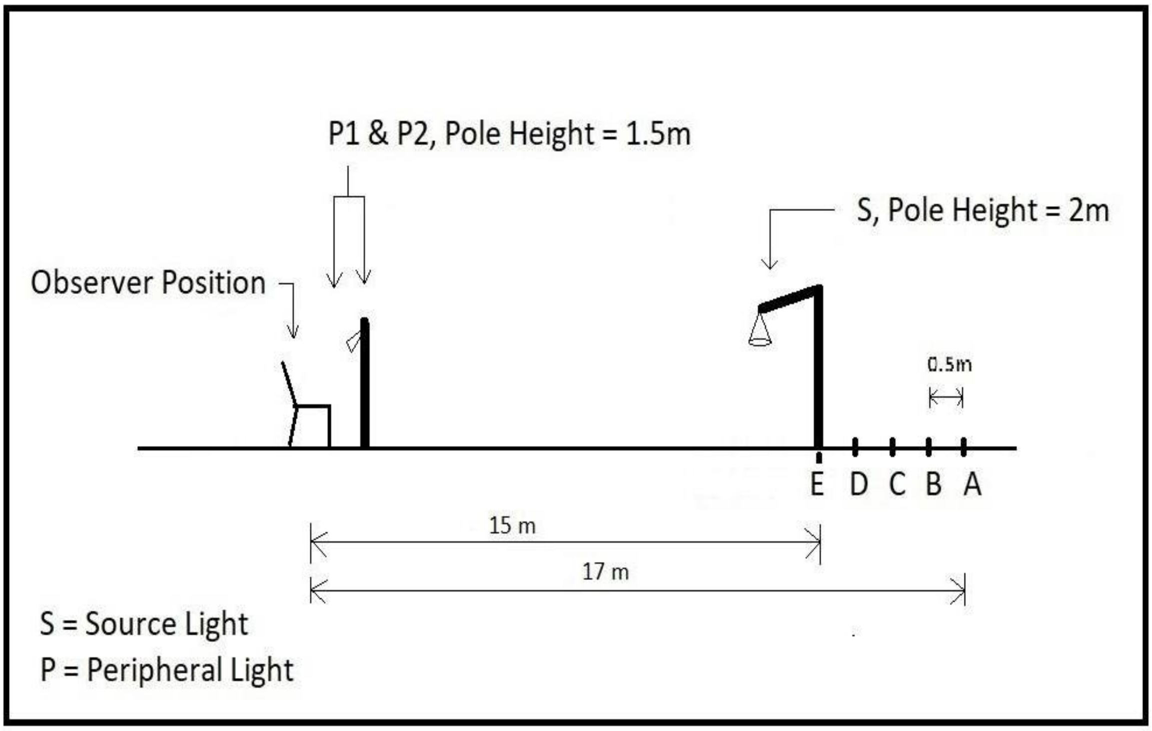


Figure - 7

The above figure shows the side view of the experimental setup.

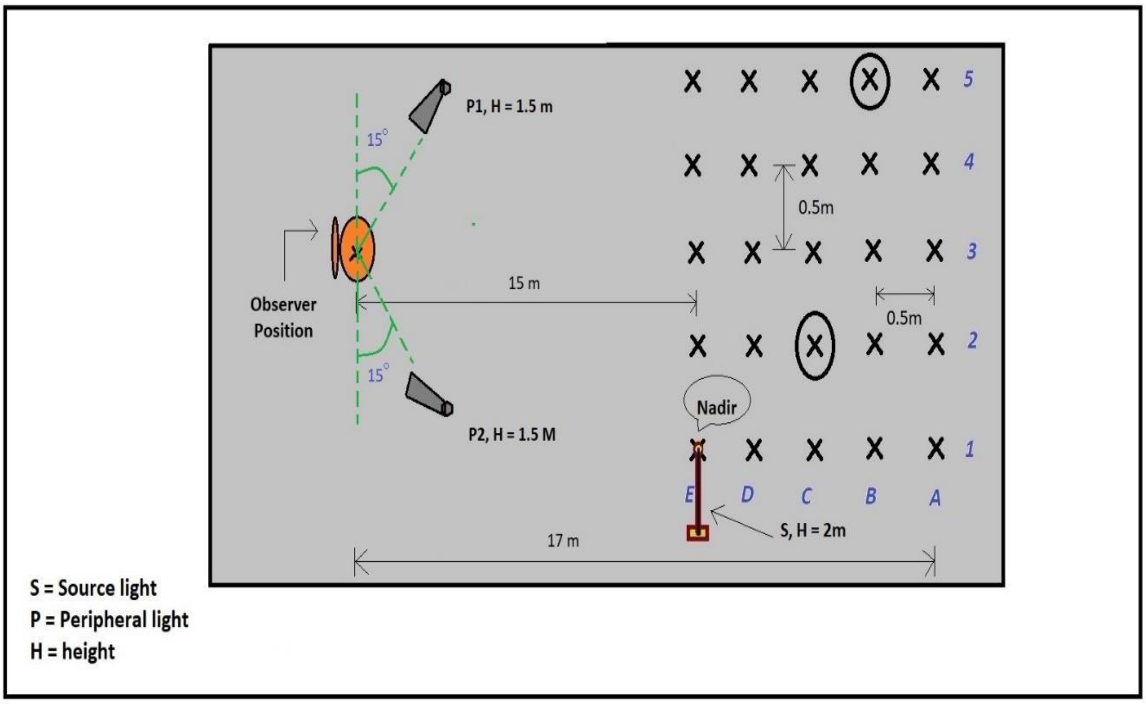


Figure - 8

This above figure represents the top view of the experimental setup.

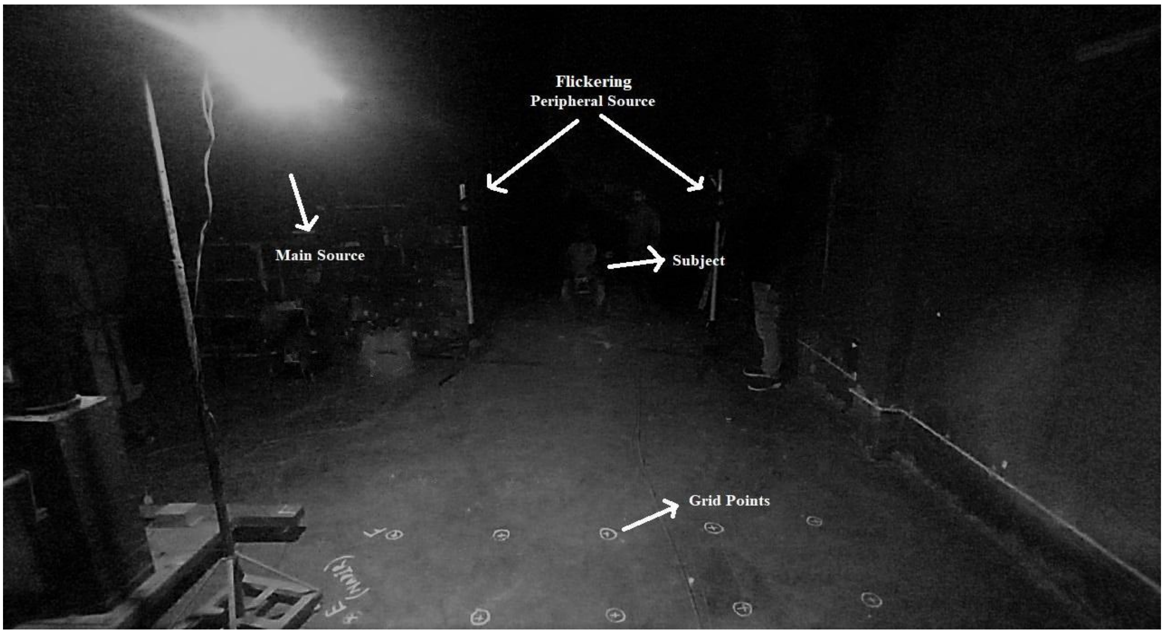


Figure - 9

The above picture was taken from the laboratory while the experiment was going on.

4.1.c Behavioral experiment and procedure:

The word Behavioral refers to the motor performance of the participants in this study.

Here in this study the motor performance is quantified as the reaction time or response time. The reaction or response times of the subjects taken for each subject in the presence and absence of flickering glare source under different CCT for further data analysis.

Procedure to record the reaction time:

Participants were made to wear the active shutter glass synced with the reaction time measuring device. The lenses of the shutter glass are opaque in normal conditions which block all the light to pass and needless to say in this condition the observer is not able to see what is in front of him/her.

Among the two push buttons attached to the reaction time measuring device, one was in the hand of the researcher(B1) and another was given to the observer(B2). The subjects/observers were asked to push the assigned button the moment they had spotted the object in front of them.

So, after the placement of the object at a desired position on the grid the researcher was supposed to push the button in his hand (B1). The moment he pushed the button, the action was starting with an accurate millisecond level stopwatch and at that particular moment the active shutter glass lenses were going transparent for next 700 milliseconds precisely.

For this 700 ms time window when the glass became transparent, it was obvious that the observer could see the frontal vicinity and his/her object recognition process started. And like it was said earlier also, subjects were asked to press the button(B2) when they had spotted an object in front of them.

And the moment the observer hit the push button from the beginning of the time window, that time was recorded in millisecond scale and displayed in the LCD screen of the measuring device. That is the reaction time of the observer.

Though it was not mandatory to detect the object in that particular time window of 700 ms.

The image of the flowchart **(Figure -10)** explains the procedure in brief.

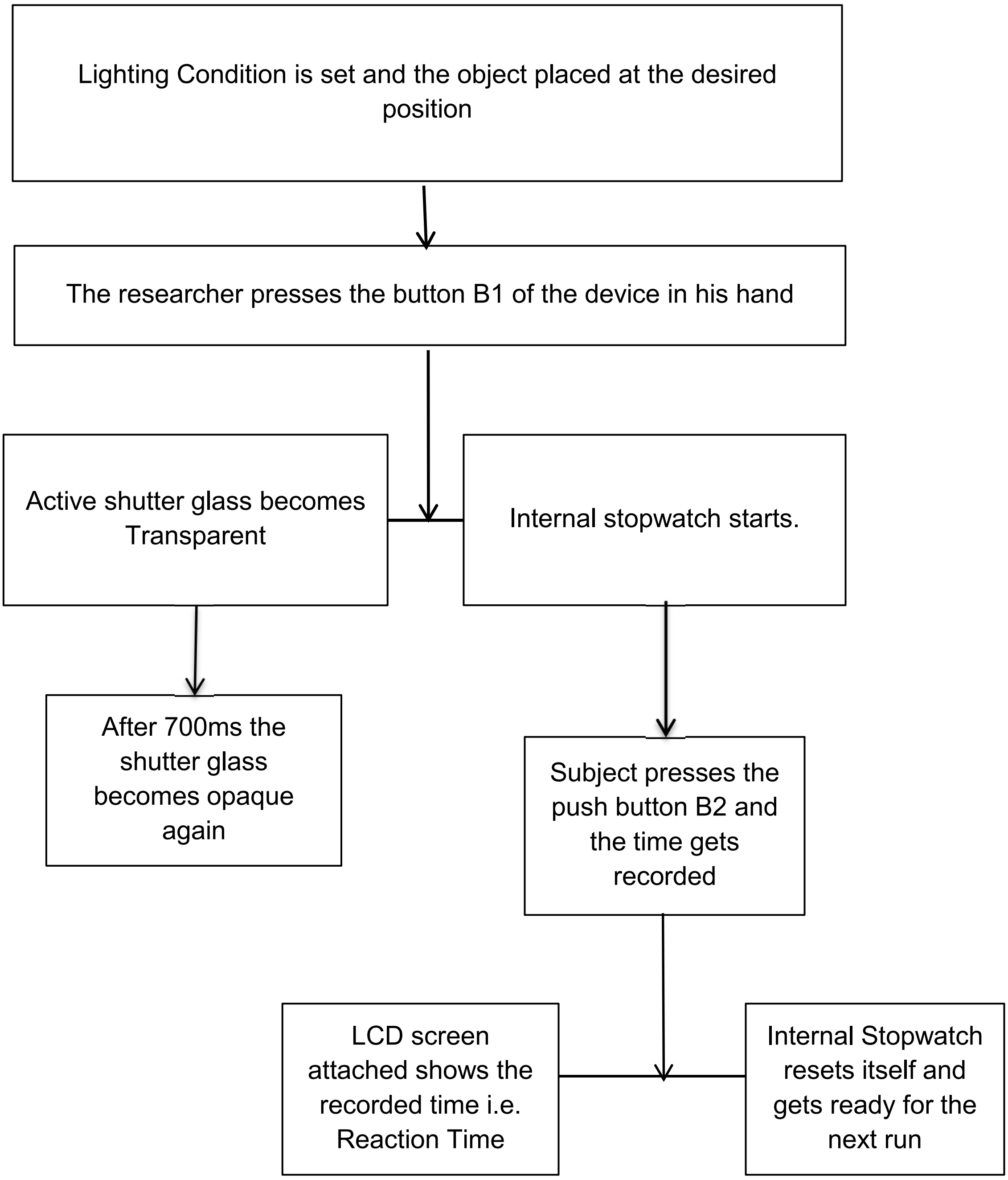


Figure - 10

Procedure of the Trials:

We can say overall this study can be divided into two parts. In the first part, the previously mentioned yellow object was placed at the grid points C2 and B5 hiding it from the observers, in a random and repetitive manner for all three CCT levels of the main source. The CCT levels were 3000K, 4500K, and 6000K; SD: 5%. In this step the peripheral glare sources were turned off. To create a positive contrast between the target and background the object was placed behind the main source. The CCTs of the main source were changed using an android based application and was also verified using a Konika-Minolta CL-70F colorimeter.

Now under each CCT level placing the object at both C2 and B5 positions the reaction time was measured.

In the second part the experiment procedure remained the same but here two peripheral glare sources were introduced the way it was discussed earlier.

Four frequency values of the flicker are taken in this study that are, 3Hz, 5Hz, 8Hz and 10 Hz.

Keeping the flicker frequency constant the CCTs were varied and reaction time was measured in the same manner like the first part. That means there were total of 24 reaction times data (4 frequencies * 3 CCTs * 2 Positions) were taken from each participant in the second part.

Distance between different components were measured and fixed using a laser distance meter, Fluke 406E.

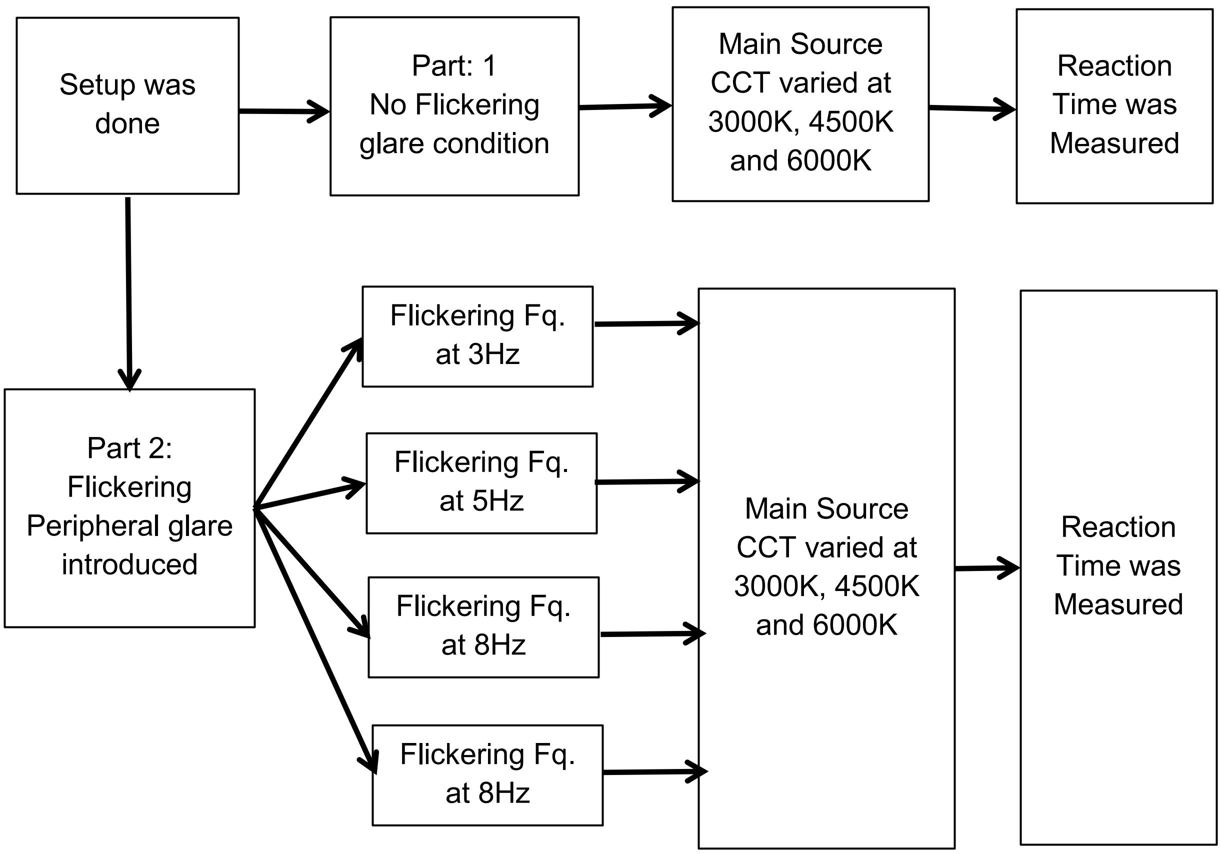


Figure - 11

4.2 Subjects:

Five healthy physiologically and neurologically intact participants (four males, and one female, mean age 22.5 yrs., S.D. ± 5%) participated in this study. All the participants reported normal or corrected to normal vision.

Upon arrival, participants were made comfortable and provided refreshments before they were assigned to perform the required task

They were provided with detailed understanding of the entire experimental procedure and signed informed consent before participating in the experiment. The protocol was cleared by the Institutional Ethics Committee.

The following list contains the details of the Participants

Sl No.	Participant	Gender	Age
1.	Subject A	Male	21
2.	Subject B	Male	23
3.	Subject C	Male	21
4.	Subject D	Female	25
5.	Subject E	Male	24

Table - 4

CHAPTER - 5

RESULTS AND ANALYSIS

5.1 Data Recording:

Like it was discussed in chapter 4, The reaction time data was collected using the custom made reaction time measuring device.The data was presented in a tabular form for each event for each participant for further analysing the data. The Table of data for Subject A is given below as an example.

Sl No.	CCT of Main Source	Flickering Frequency	Reaction Time	Object Position	Discomfort Rating
1	3000k	OFF	0.83	C2	1
2	3000k	OFF	1.13	B5	1
3	3000k	3Hz	0.82	B5	2
4	3000k	3Hz	1.967	C2	3
5	3000k	5Hz	1.351	C2	2
6	3000k	5Hz	1.275	B5	3
7	3000k	8Hz	1.68	C2	3
8	3000k	8Hz	0.995	B5	3
9	3000k	10Hz	1.11	B5	3
10	3000k	10Hz	1	C2	2
11	4500K	OFF	0.6	C2	1
12	4500K	OFF	1.11	B5	1
13	4500K	3Hz	0.67	C2	1
14	4500K	3Hz	1.07	B5	2
15	4500K	5Hz	0.4	B5	2
16	4500K	5Hz	0.85	C2	2
17	4500K	8Hz	1.03	C2	3
18	4500K	8Hz	0.85	B5	2
19	4500K	10Hz	0.79	C2	2
20	4500K	10Hz	0.935	B5	3
21	6000K	OFF	0.42	C2	1
22	6000K	OFF	0.67	B5	1
23	6000K	3Hz	0.54	C2	2
24	6000K	3Hz	0.63	B5	2
25	6000K	5Hz	0.71	C2	2

26	6000K	5Hz	1.04	B5	4
27	6000K	8Hz	0.22	B5	3
28	6000K	8Hz	0.62	C2	2
29	6000K	10Hz	0.47	C2	3
30	6000K	10Hz	0.67	B5	3

Table - 5

As it can be seen from the data table, reaction time for each run was recorded and another data 'Discomfort Rating' was also taken from the users verbally. As this glare falls under the discomfort glare category and discomfort depends on the subject's perspective. These ratings are such that 1 stands for lowest discomfort level and 5 stands for the maximum discomfort level. Participants were asked to rate their level of discomfort accordingly.

5.2 Results and Analysis:

After recording the data it was analysed in Excel and different graphs were plotted to understand the final result.

Here in this study an average based analytical approach has been taken. All the reaction times for different participants were averaged to get an Average Reaction time value at a particular CCT and Glare frequency. Here No-glare condition has been represented by both 'OFF' and '0Hz' frequency condition.

As here the avg value has been used for final analysis which in turn has helped to minimise the observer specific biases and position biases.

At first three graphs were plotted between Flickering frequency and Reaction time keeping the CCT value constant. Graphs are at Figure-12, Figure-13 and Figure-14 respectively. X-axis represents the frequency of the flickering glare sources and Y-axis represents the Reaction time.

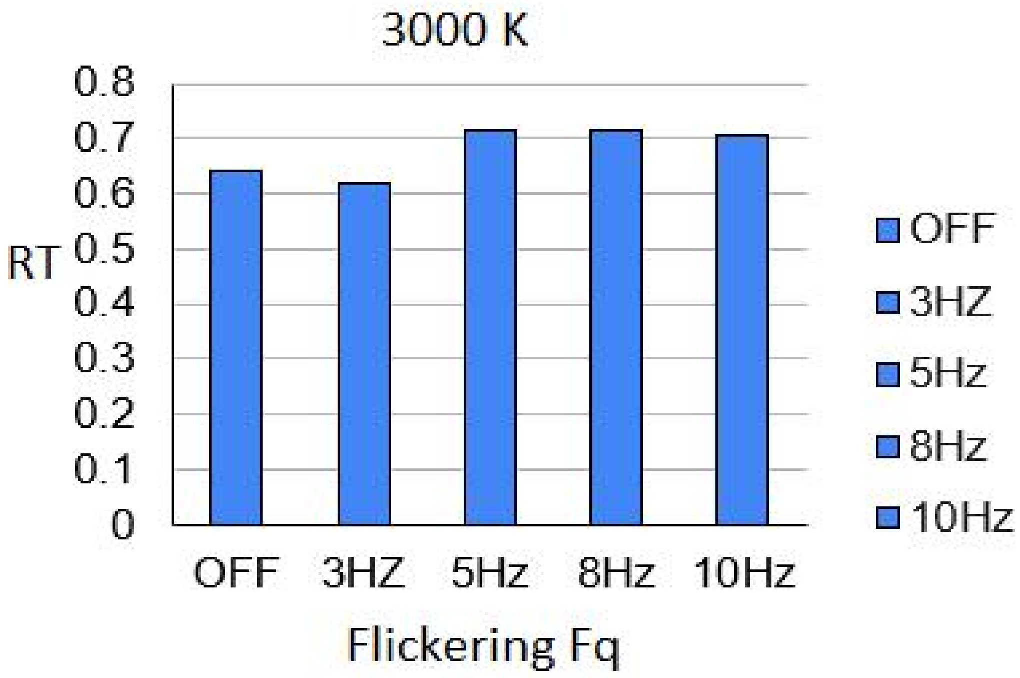


Figure - 12

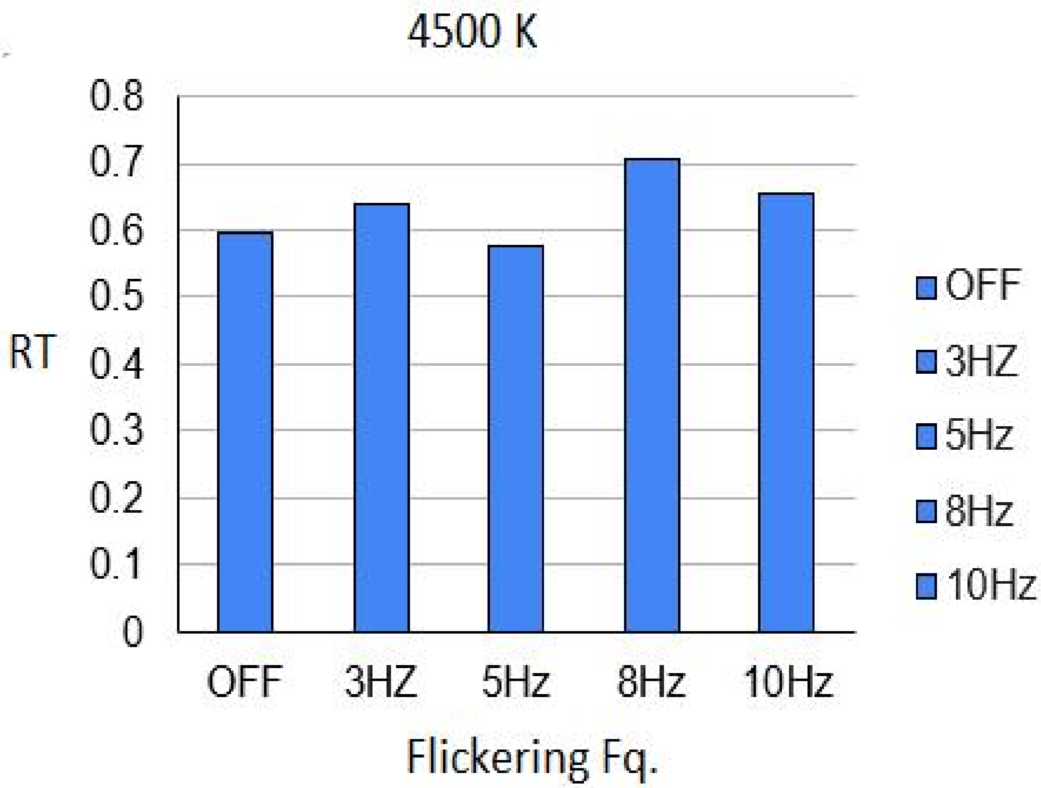


Figure - 13

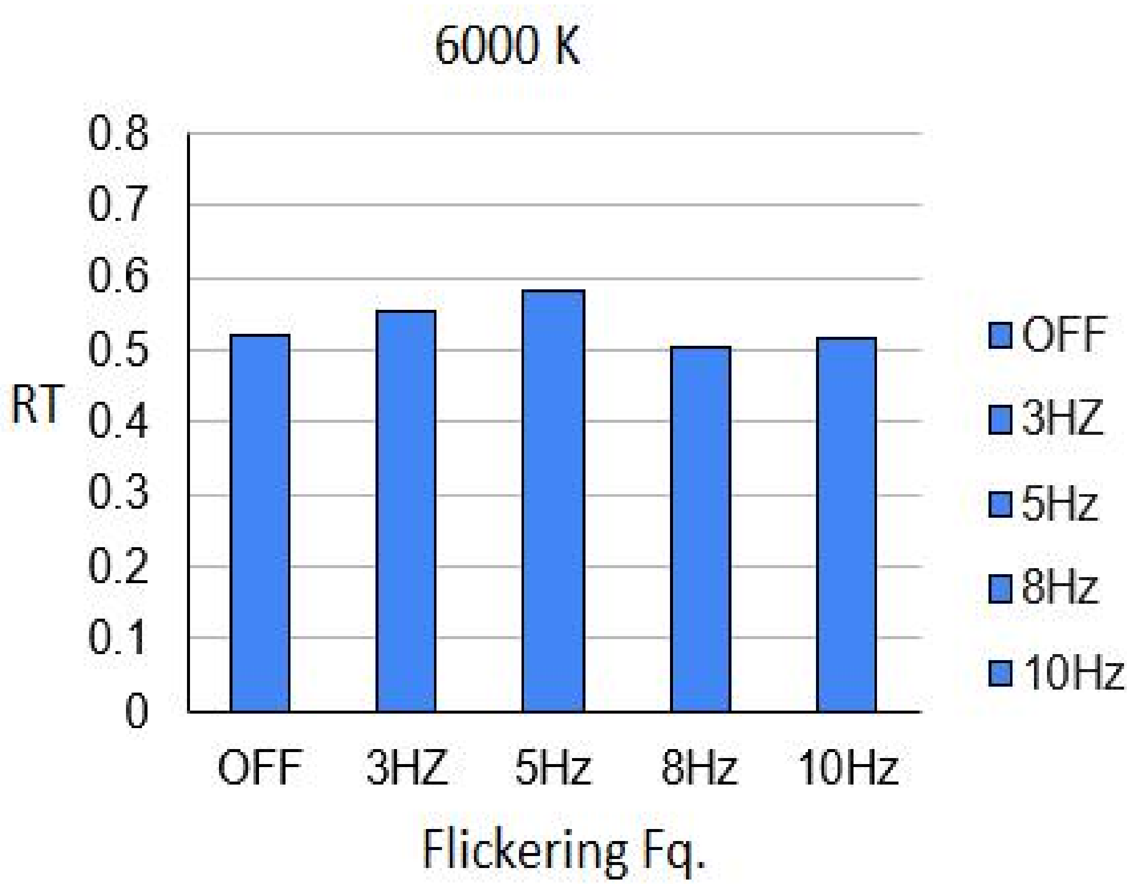


Figure - 14

Now to understand how reaction is changing with the CCT under a particular flickering glare, five other graphical plots were formed. This time the frequency of the glare source was kept constant. These graphs are shown in Figure-15, Figure-16, Figure -17, Figure-18, and Figure- 19. Here the X-axis represents The CCT of the main source and Y-axis represents the Reaction time.

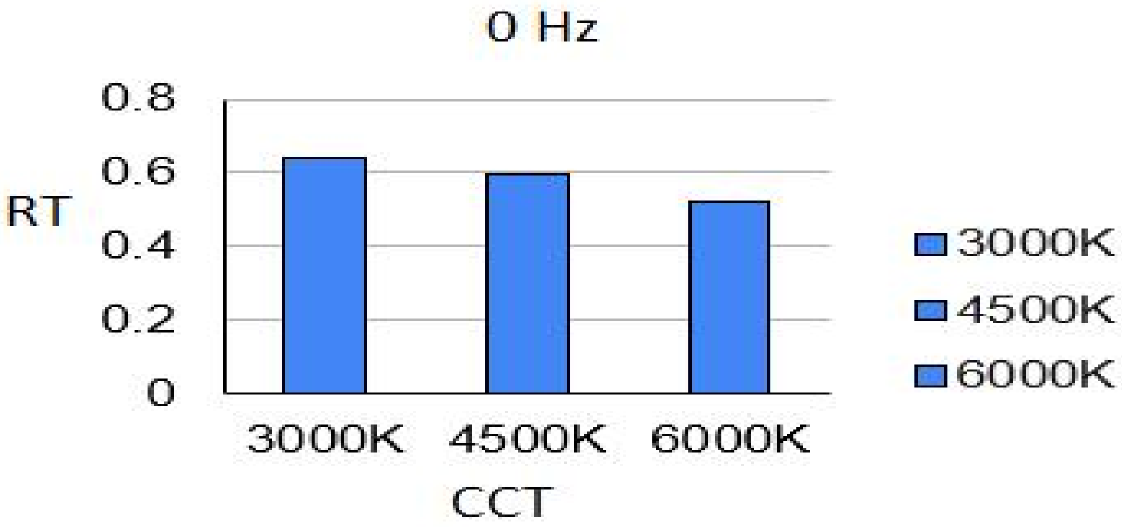


Figure - 15

Figure - 16

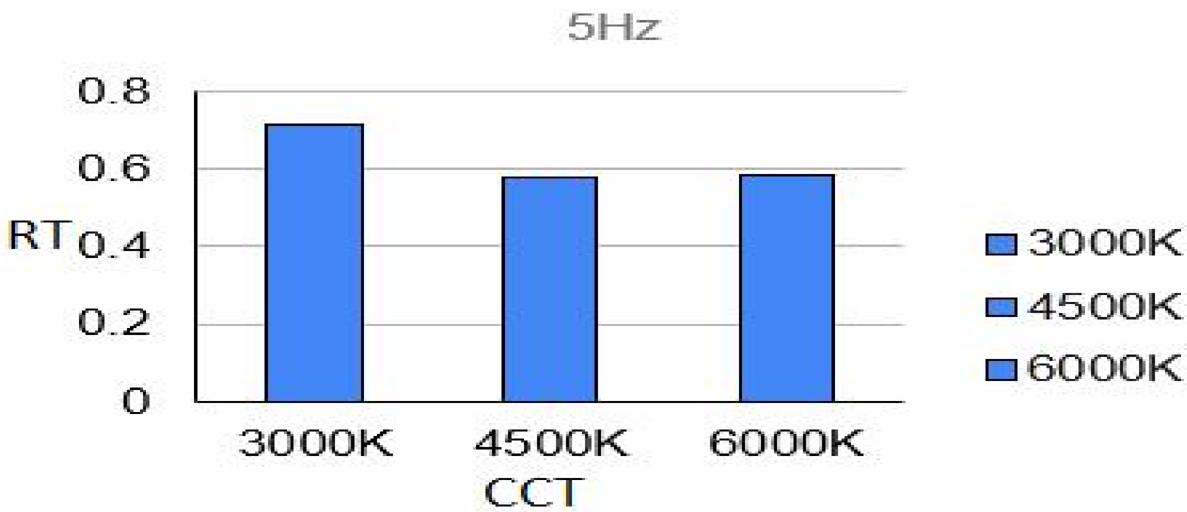


Figure - 17

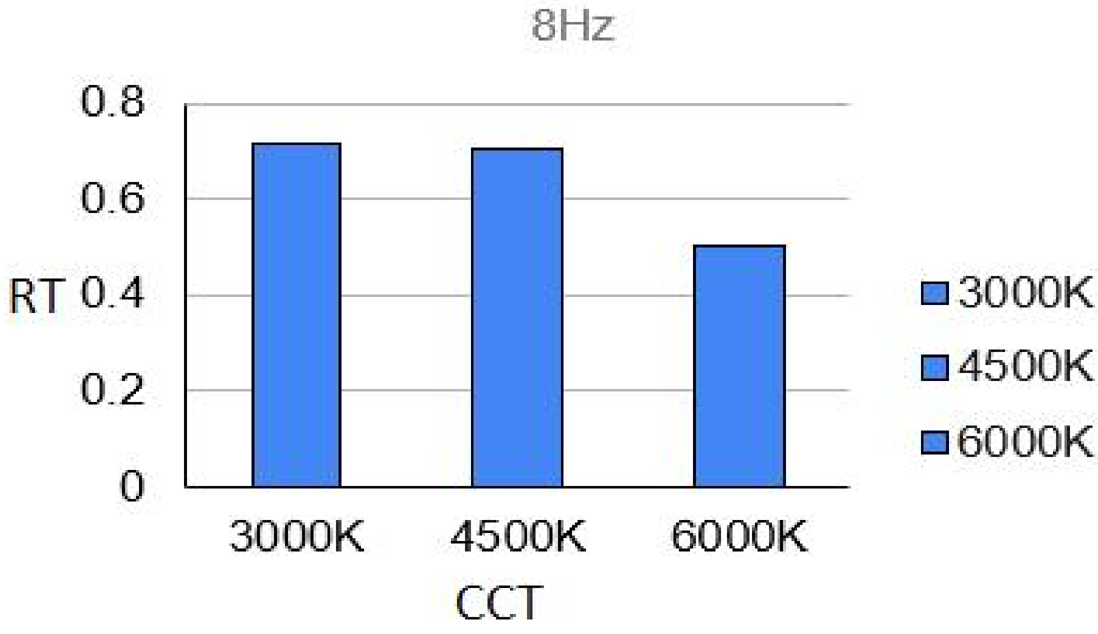


Figure - 18

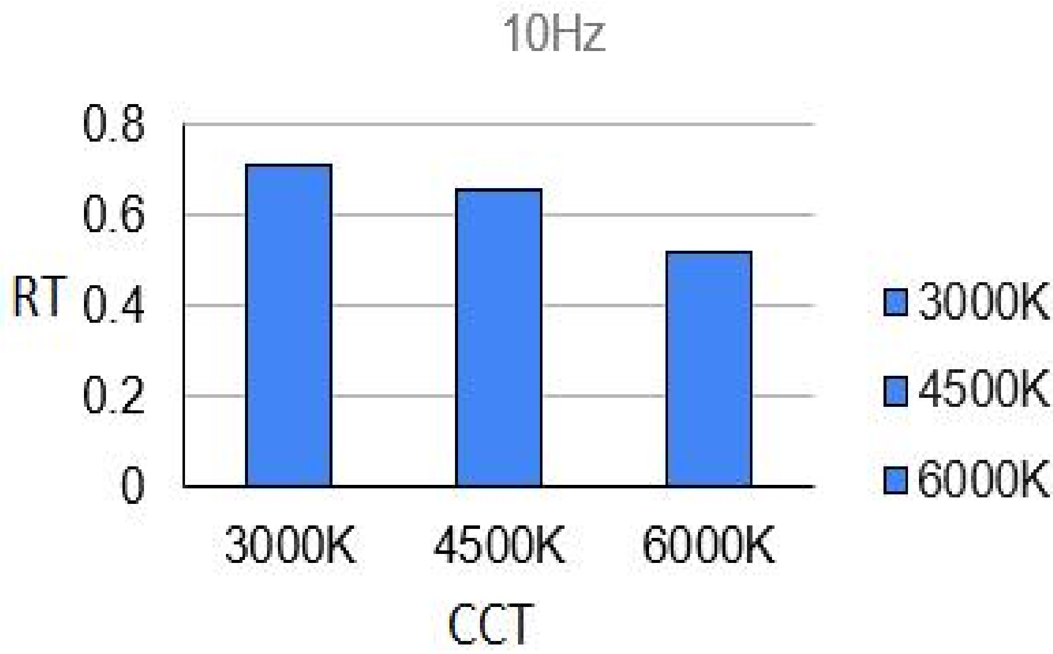


Figure - 19

CCT vs RT graphs at 8Hz, 10Hz flickering frequencies and at no-flickering glare conditions demonstrate that the reaction time declines as main source CCT increases (highest at 3000K and lowest at 6000K), whereas the graphs at 3 Hz flickering frequency reveal that reaction time is highest at 4500K and lowest at 6000K. Graph at 5Hz records a highest RT value at 3000K and the lowest RT value at 4500K.

Though the pattern at 3Hz and 5Hz are different than the other three(8, 10, no-flicker) it can be seen that the difference b/w the RTs of 4500K and 6000K at 5Hz and the difference b/w the RTs of 4500K and 3000K at 3Hz are very low compared to the other jumps. So as for the general trend it can be concluded that at a particular Peripheral Glaring condition, reaction time or human response time decreases.

Moreover, when the reaction times are plotted against flickering frequency keeping the CCTs of the main source constant, three particular graph is generated from the data. It clearly shows that flickering at peripheral position increases the reaction times of the observer from the condition, where there is no flickering in peripheral position. Detailed table, containing the measured data, is given in **Table 6.**

CCT	Flickering Fq.				
	OFF	3 Hz	5 Hz	8 Hz	10 Hz
3000 K	0.641 s	0.6207 s	0.7176 s	0.7165 s	0.708 s
4500 K	0.595 s	0.639 s	0.577 s	0.706 s	0.6545 s
6000K	0.522 s	0.555 s	0.584 s	0.505 s	0.516 s

Table - 6

Another graph between RT vs CCT was plotted including reaction time from all the frequencies at once, shown in **figure-20** . That graph represents the same analytical results discussed before. 0Hz is representing the state when the glare sources were off. The general trend is visible that with increase in frequency the reaction time increases. And we can see a negative slope with an increase in the CCT value.

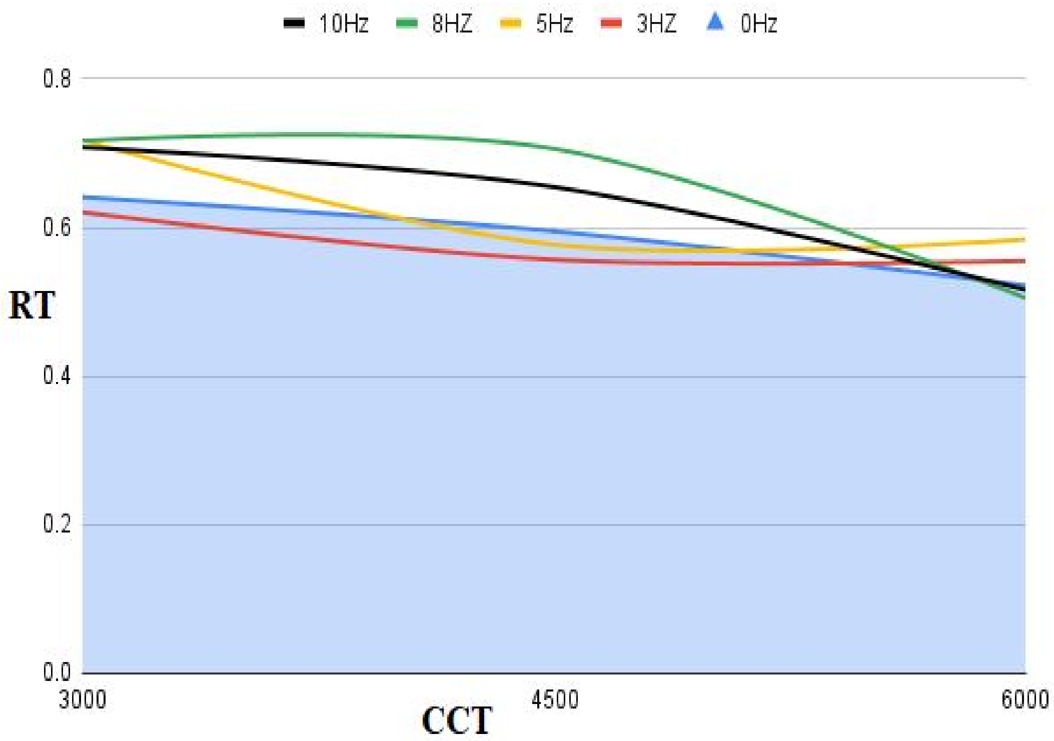


Figure - 20

The 'Discomfort rating' was taken from the users after each run. Subjects were asked verbally to rate the discomfort level for that particular lighting scene on a scale of 1 to 5. Where 1 was not at all uncomfortable and 5 being extremely uncomfortable that he/she could barely see. The avg of all the participant's ratings were calculated for each CCT-Flickering Frequency combination. Table for that data is given below in Table No. 7.

CCT	Flickering Fq.				
	OFF	3 Hz	5 Hz	8 Hz	10 Hz
3000 K	1.4	2.4	2.3	2.5	2.8
4500 K	1.1	1.9	2.2	2.6	2.7
6000K	1.2	2.1	2.6	2.6	3.1

Table - 7

Graphical representation of the change in discomfort rating values with the flickering frequency is shown below in **Figure - 21.**

From that graph it can be seen that for a specific CCT, discomfort of the subject has increased with the increase in flicker frequency value of the peripheral glare sources for all values of main source CCT.

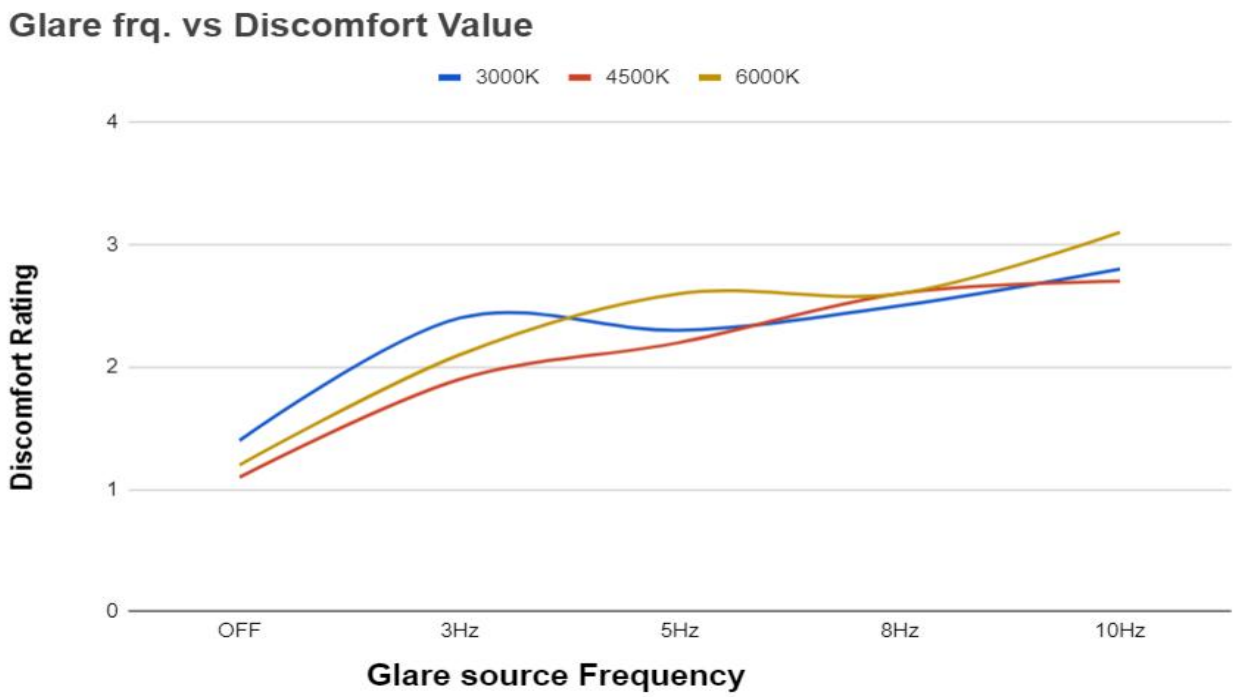


Figure - 21

CHAPTER - 6

DISCUSSION AND FUTURE SCOPE

6.1 Discussion

This study unequivocally demonstrates that peripheral flickering glare significantly slows down the observer's ability to recognise objects. It lengthens the period of time that is taken to detect the object and respond to it.

Additionally, it has also shown that regardless of the flickering frequency shift, observer reaction time shortens when CCT of the primary source increases. Additionally, it is discovered from the participant's overall Behavioral investigation that peripheral flickering glare source produces higher amount of discomfort and annoys the driver.

The discomfort rating taken from the subjects suggested the same thing. With the increase in the flickering value the discomfort level of the subjects has increased regardless of the CCT of the main source. And that points to an interesting factor. That is, for a fixed CCT, when the flickering frequency increased both the reaction and the discomfort level increased. So there is a chance that not only the visual responses of an eye under glare played a role for the increase in the reaction time, but the psychological effects of the flickering galre might have a role to play.

In a prior study it was found that the average reaction time of drivers dramatically gets reduced for higher CCTs of the primary and peripheral sources, and small target visibility of the lighting condition also rises.[1]

From another previous work by De Lange, it was known that the flicker visibility is dependent on the nature of the light fluctuation's waveform[2]. And this study doesn’t conflict with their findings.

So in a nutshell, it can be concluded that when creating a road lighting plan, the designer must reduce the factors that could lead to peripheral flicker. He should also check the lighting situation and the occurrence of flickering after installing the plan, and if flicker is present, the waveform should be examined and the necessary corrective action should be taken. Additionally, it will be beneficial if the lighting plan uses light sources with a high CCT.

6.2 Future Scope of the Study:

This study was undertaken with the understanding that all external variables, including ambient temperature, atmospheric precipitation, participant mood, circadian timing, etc., have little to no impact on the outcomes of the experiments. Additionally, the entire experiment is carried out in a laboratory setting under optimal conditions. The outcome so achieved can be contested in a real-time field experiment where a driver is required to complete the identical job in these particular lighting conditions, taking into account external factors.

Another important scope can be cognitive study. As we are dealing with a discomfort glare so there can be psychological factors generated from the glare as object detection is a complex mental process. So a cognitive study in parallel with this behaviour study can give way more clear results.

The brain waves can be measured using an EEG while repeating the same trials and then analysing the data that future researchers can get more insights on how the brain activity changes with or without the presence of a flickering peripheral glare source and the relation of brain activity with the changing flickering frequency and main source CCT.

Reference:

[1]. Goswami, Aiswarya Dev, et al. "A Laboratory based Study on the Effect of CCT Change of LED Light Sources on Reaction Time and Visibility Level for Object Recognition." *Optik* (2022): 169353.

[2]. De Lange H. 1961. Eye’s response at flicker fusion to square-wave modulation of a test field surrounded by a large steady field of equal mean luminance. J Opt Soc Am. 51(4):415–421.

CHAPTER - 7

APPENDIX

7.1 Items Used

A. Halonix 12W Smart RGB LED Bulb:

Figure -22

This Smart LED light was used as a main source. Which was mounted at a height of 2 meters.

Feature and Specification:

1. It is a 230V, 12W bulb with a weight of 200 grams.
2. It compatible with WiFi 2.4 GHz.
3. Base - B22
4. Rated Lumen Output: 810 lumen (Luminous Flux)
5. It is controlled through Android Application.

B. 12V, 9W LED Lights

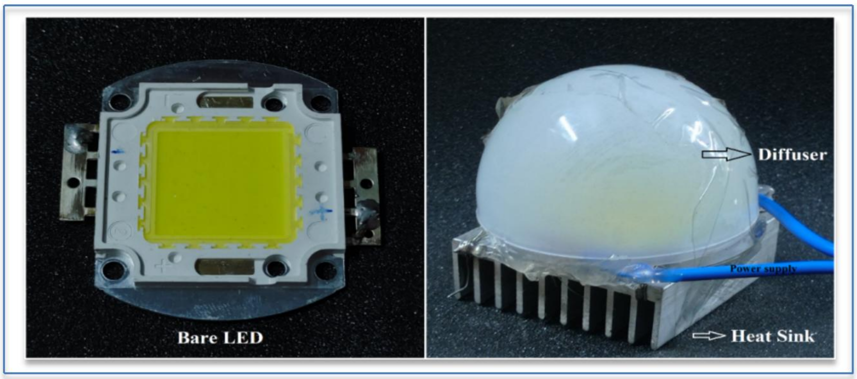


Figure - 23

These LEDS were used to create the peripheral glare source. These sources are built at the laboratory by putting 12 Volts phosphor coated LED chips on heat sinks. They have a fixed CCT value of 5500 K, when they are in switch-on condition with full intensity.

C. Object:

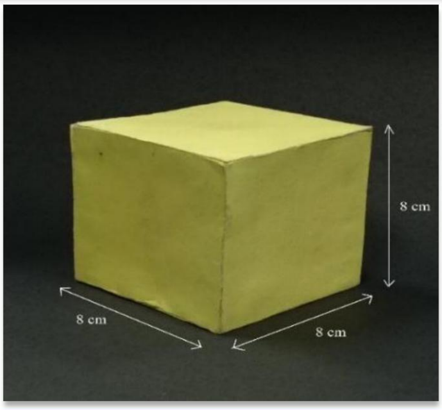


Figure - 24

A yellow colored cube of side 8cm is used as the target object for the observer, given in Fig. 2. It is said that the desired reflectance of the object must fall in between 20% to 50%[2]. This study uses a target object, which has an average reflectance of 37.5% in all CCT levels and the reflectance is measured by a Metravi 1310 digital light meter.

D . Reaction Time Measuring Device:

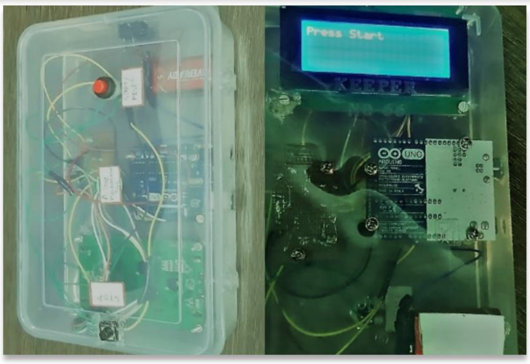


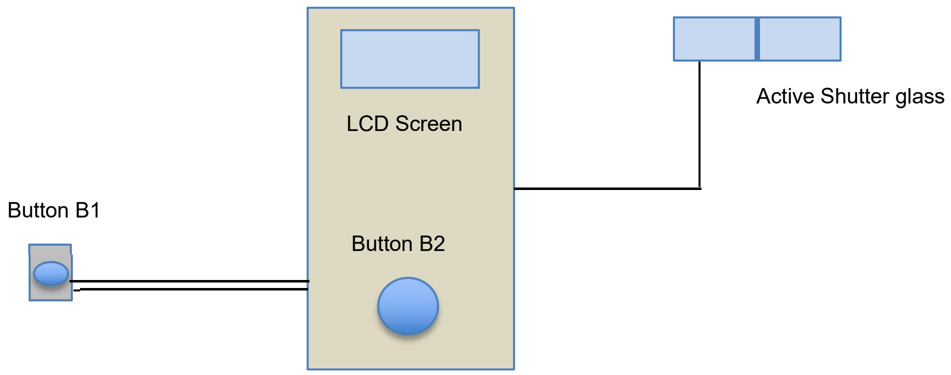
Figure - 25(a)

Figure - 25(b)

This is a battery powered an Arduino based microcontroller-controlled device developed in Illumination Engineering section of Jadavpur University Electrical Engineering Department, given in Fig. 25(a), to measure the reaction times of the observers for object recognition and it is coupled and synchronised with a programmed active shutter glass, given in Fig. 25(b).

Active Shutter Glass: In active shutter glass there is a liquid crystal layer in each eye's glass. That liquid crystal has the ability to change from being transparent to opaque when voltage is applied. Using a timing signal the glasses are controlled. By that way visibility of the person wearing the glass can blocked as per the requirement. Here in this device that signal is generated using the Arduino Uno.

That device has two push buttons one is supposed to be operated by the researcher(B1) and another one is by the subject(B2). An LCD Screen attached to this device also which shows the recorded reaction time. The block diagram of the device is given below.



E. Flickering controller Circuit:

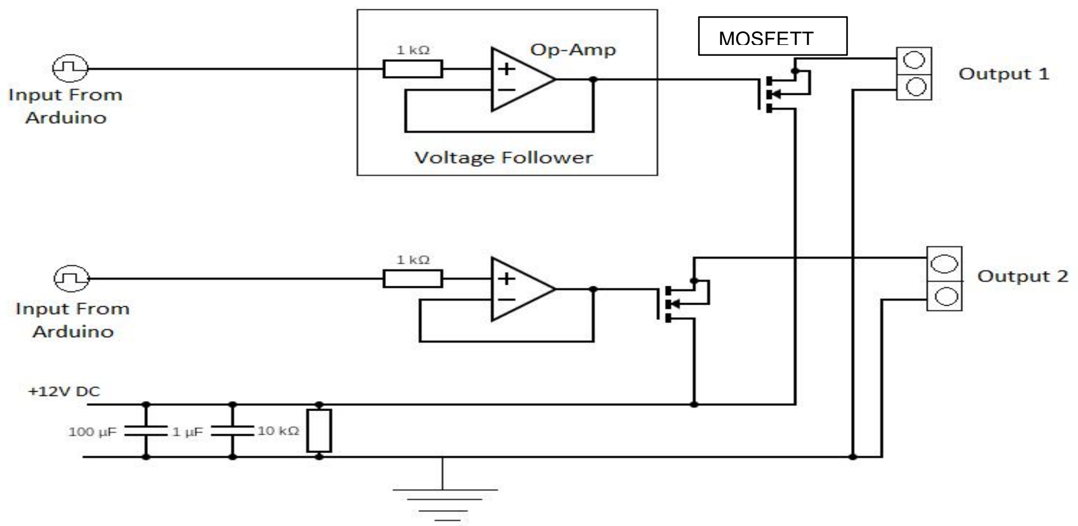


Figure - 26

This Circuit to control the flickering frequency was developed in the Illumination Section Laboratory of Jadavpur University Department of Electrical Engineering .

For the 12 Volt supply two 12 Volts drivers are used two convert 240 Volts AC to 12 Volts DC.

An Arduino Uno was used to generate the 5V pulses as per the frequency requirement. Those pulses were carried forward by the Op-Amp based voltage follower ckt. At High, When the gate of the MOSFET was becoming 5V, it was getting ON. Thus the current was able to flow through the 9W LED bulbs turning the lights on But At Low, the gate potential of the MOSFET is Zero. Hence the Light went off.

Original Photo of the device shown Below.

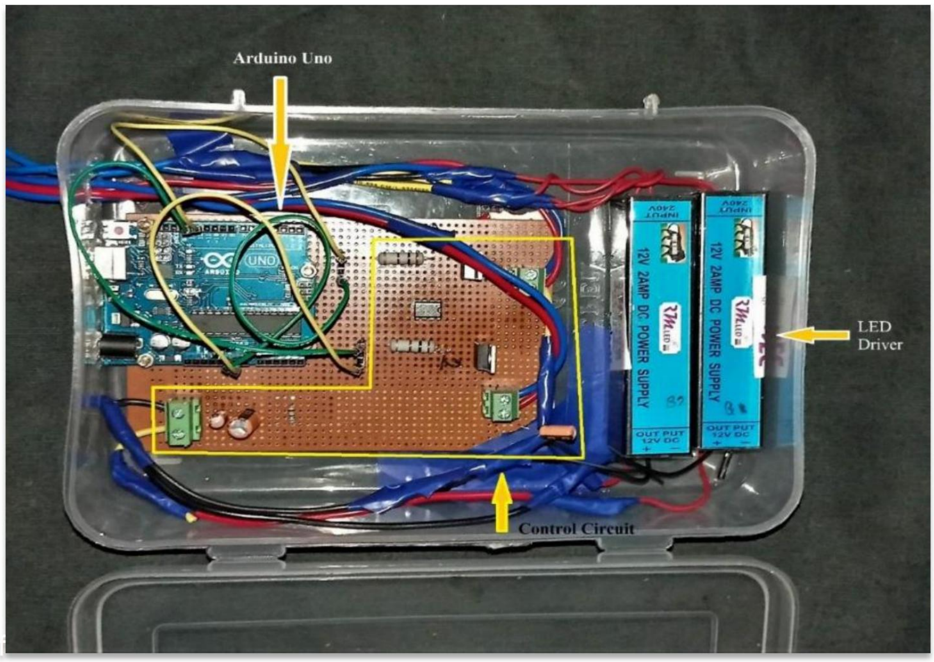


Figure - 27

Components used in the Flickering Control ckt.

1. Arduino Uno:

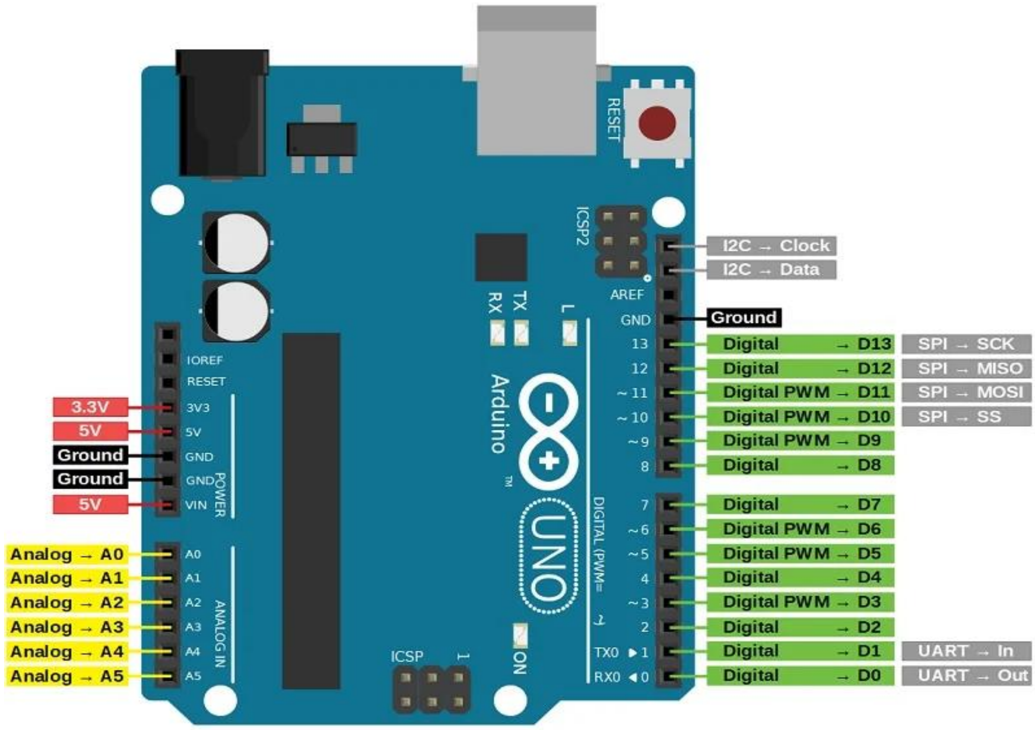


Figure - 28

[Figure Collected from https://robu.in]

Details of the pins:

Vin: This is the input voltage pin of the Arduino board used to provide input supply from an external power source.
5V: This pin of the Arduino board is used as a regulated power supply voltage and it is used to give supply to the board as well as onboard components.
3.3V: This pin of the board is used to provide a supply of 3.3V which is generated from a voltage regulator on the board**GND:** This pin of the board is used to ground the Arduino board.
Reset: This pin of the board is used to reset the microcontroller. It is used to Resets the microcontroller.
Analog Pins: The pins A0 to A5 are used as an analog input and it is in the range of 0-5V.
Digital Pins: The pins 0 to 13 are used as a digital input or output for the Arduino board.
Serial Pins: These pins are also known as a UART pin. It is used for communication between the Arduino board and a computer or other devices. The transmitter pin number 1 and receiver pin number 0 is used to transmit and receive the data resp.
External Interrupt Pins: This pin of the Arduino board is used to produce the External interrupt and it is done by pin numbers 2 and 3.
PWM Pins: This pins of the board is used to convert the digital signal into an analog by varying the width of the Pulse. The pin numbers 3,5,6,9,10 and 11 are used as a PWM pin.
LED Pin: The board has an inbuilt LED using digital pin-13. The LED glows only when the digital pin becomes high.
AREF Pin: This is an analog reference pin of the Arduino board. It is used to provide a reference voltage from an external power supply.

2. N channel MOSFET IRFZ44N:

Figure - 29

Philips Semiconductors | Product specification

N-channel enhancement mode TrenchMOS™ transistor | **IRFZ44N**

GENERAL DESCRIPTION

N-channel enhancement mode standard level field-effect power transistor in a plastic envelope using '**trench**' technology. The device features very low on-state resistance and has integral zener diodes giving ESD protection up to 2kV. It is intended for use in switched mode power supplies and general purpose switching applications.

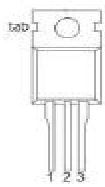
QUICK REFERENCE DATA

SYMBOL	PARAMETER	MAX.	UNIT
V_{DS}	Drain-source voltage	55	V
I_D	Drain current (DC)	49	A
P_{tot}	Total power dissipation	110	W
T_j	Junction temperature	175	˚C
$R_{DS(ON)}$	Drain-source on-state resistance V_{GS} = 10 V	22	mΩ

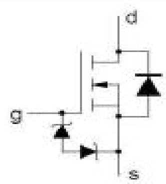
PINNING - TO220AB

PIN	DESCRIPTION
1	gate
2	drain
3	source
tab	drain

PIN CONFIGURATION



SYMBOL



LIMITING VALUES

Limiting values in accordance with the Absolute Maximum System (IEC 134)

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{DS}	Drain-source voltage	-	-	55	V
V_{DGR}	Drain-gate voltage	R_{GS} = 20 kΩ	-	55	V
$\pm V_{GS}$	Gate-source voltage	-	-	20	V
I_D	Drain current (DC)	T_{mb} = 25 ˚C	-	49	A
I_D	Drain current (DC)	T_{mb} = 100 ˚C	-	35	A
I_{DM}	Drain current (pulse peak value)	T_{mb} = 25 ˚C	-	160	A
P_{tot}	Total power dissipation	T_{mb} = 25 ˚C	-	110	W
T_{stg}, T_j	Storage & operating temperature	-	- 55	175	˚C

ESD LIMITING VALUE

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_C	Electrostatic discharge capacitor voltage, all pins	Human body model (100 pF, 1.5 kΩ)	-	2	kV

THERMAL RESISTANCES

SYMBOL	PARAMETER	CONDITIONS	TYP.	MAX.	UNIT
$R_{th\ j\text{-}mb}$	Thermal resistance junction to mounting base	-	-	1.4	K/W
$R_{th\ j\text{-}a}$	Thermal resistance junction to ambient	in free air	60	-	K/W

Data Sheet of IRFZ44N N channel MOSFET

3. Op-Amp IC : TL082CP

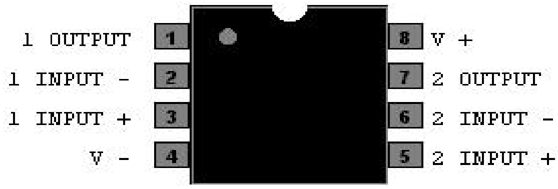


Figure - 30

TEXAS INSTRUMENTS

TL082-N

www.ti.com SNOSBW5C – APRIL 1998 – REVISED APRIL 2013

TL082 Wide Bandwidth Dual JFET Input Operational Amplifier

Check for Samples: TL082-N

FEATURES

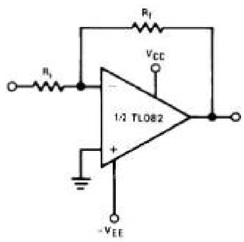
- Internally Trimmed Offset Voltage: 15 mV
- Low Input Bias Current: 50 pA
- Low Input Noise Voltage: 16nV/√Hz
- Low Input Noise Current: 0.01 pA/√Hz
- Wide Gain Bandwidth: 4 MHz
- High Slew Rate: 13 V/μs
- Low Supply Current: 3.6 mA
- High Input Impedance: $10^{12}\Omega$
- Low Total Harmonic Distortion: ≤0.02%
- Low 1/f Noise Corner: 50 Hz
- Fast Settling Time to 0.01%: 2 μs

DESCRIPTION

These devices are low cost, high speed, dual JFET input operational amplifiers with an internally trimmed input offset voltage (BI-FET II™ technology). They require low supply current yet maintain a large gain bandwidth product and fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The TL082 is pin compatible with the standard LM1558 allowing designers to immediately upgrade the overall performance of existing LM1558 and most LM358 designs.

These amplifiers may be used in applications such as high speed integrators, fast D/A converters, sample and hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The devices also exhibit low noise and offset voltage drift.

Typical Connection



Connection Diagram

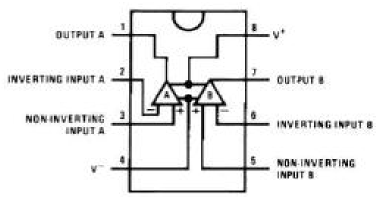


Figure 1. PDIP/SOIC Package (Top View)
See Package Number D0008A or P0008E

Data Sheet of TL082CP

4. **Capacitor:**

a. One 100 μF, 63V Capacitor

b . One 1μF, 63V Capacitor

5. Resister:

a) Two 100 Ohm resistor

b) One 10K Ohm resistor

The Arduino Programming used to control the flickering Frequency is:

```
// the setup function runs once when you press reset or power the board
void setup() {
// initialize digital pin LED_BUILTIN as an output.
pinMode(13, OUTPUT);
pinMode(12, OUTPUT);
Serial.begin(9600);
delay(100);
}
void loop() {
Serial.println("LED is now Blinking");
digitalWrite(13, HIGH);
digitalWrite(12, HIGH); // turn the LED on (HIGH is the voltage level)
delay(50);
 //delay(62.5);
//delay(100);
//delay(166.67);
 digitalWrite(13, LOW);
digitalWrite(12, LOW);// turn the LED off by making the voltage LOW
delay(50);
//delay(62.5);
//delay(100);
//delay(166.67);

}
//10Hz = 50ms, 8Hz = 62.5 ms, 5Hz = 100ms, 3hz = 166.67ms
```

F. Konika-Minolta CL-70F Photometer

Konica Minolta CL-70F Photometer

Fig - 31

Main Specifications of CL-70F

Model	CRI Illuminance Meter CL-70F
Illuminance meter class	Conforms to requirements for Class A of JIS C1609-1 : 2006 "Illuminance meters Part1:General measuring instruments; Conforms to DIN 5032 Part 7 Class C
Sensor	CMOS linear image sensor
Spectral wavelength range	380 nm to 780 nm
Output wavelength pitch	1 nm
Measuring range	Constant light: 1 to 200,000 lx; 1,563 to 100,000 K (Chromaticity display requires 5 lx or more) Flash light: 20 to 20,500 lx·s; 2,500 to 100,000 K
Accuracy (Standard Illuminant A) (*1, 2)	E_V: ±5%±1digit of displayed value
	xy: ±0.003 (at 800 lx)
Repeatability (Standard Illuminant A) (*1)	E_V: 30 to 200,000 lx: 1%+1digit; 1 to 30 lx: 5%+1digit (*3)
	xy: 500 to 200,000 lx: 0.001 (*4) xy: 100 to 500 lx: 0.002 (*4) xy: 30 to 100 lx: 0.004 (*4) xy: 5 to 30 lx: 0.008 (*4)
Visible-region relative spectral response characteristics (f1')	Within 9%
Cosine correction characteristics (f2)	Within 6%
Temperature drift (f_T)	E_V: ±5% xy: ±0.006
Humidity drift (f_H)	E_V: ±3% xy: ±0.006
Power	2 AA-size batteries (Alkaline batteries or manganese dry cells); USB bus power
Response time	Constant light (Maximum): 15 sec Constant light (Minimum): 0.5 sec Flash light: 1 to 1/500 sec (in 1-step intervals) (*5)
Color indication modes	Correlated color temperature T_{cp}, Difference from blackbody Δuv, XYZ, xy, u'v', Dominant wavelength λ_d, Excitation purity P_e, Spectral irradiance, E_v, CRI (Ra, Ri), Peak wavelength λ_p, exposure value
Other functions	Data memory: 999 data; Preset function; Auto power off function
Display languages	English, Japanese, Chinese (Simplified)
Interface	USB 2.0 Mini B
Operation temperature/ humidity range	-10 to 40°C , relative humidity of 85% or less (at 35°C) with no condensation
Storage temperature/ humidity range	-10 to 45°C , relative humidity of 85% or less (at 35°C) with no condensation
Size	73 (W)× 183 (H) × 27 (D) mm (Not including projecting buttons) D (max): 40 mm
Weight (without battery)	230 g

G. Fluke 406E LASER Distance Meter

Fig - 32

This was used to measure the distances at the time of experimental Setup.

A laser light is pointed towards the target from this device and the time taken for the reflected time is noted by the sensor attached to the device. Now multiplying the time with the speed of light and then dividing it by 2 the distance of the object is calculated.

7.2 List of Figures:

7.3List of Tables: