A study on visual preferences for effective spotlight design: Reference to painting exhibition in Indian art galleries

A thesis submitted in partial fulfilment of the requirement for the degree of ***Doctor of Philosophy*** *in* ***Design***

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Dedicated to my parents

Mr. Ashim Bhattacharjee and Mrs. Mitali Bhattacharjee

DECLARATION

I hereby declare that the work contained in this thesis entitled "A study on visual preferences for effective spotlight design: Reference to painting exhibition in Indian art galleries" is my own work done under the supervision of Dr. Swati Pal, at the Department of Design, Indian Institute of Technology Guwahati, Assam, India. I hereby declare that to the best of my knowledge; it contains no materials previously published or written by any other person, or a substantial proportion of material that have been accepted for the award of any degree or diploma at IIT Guwahati or any other educational institute, except where the due acknowledgement is made in the thesis. Any contribution made to the research by others, with whom I have worked at IIT Guwahati or elsewhere is explicitly acknowledged in this thesis. I also hereby declare that the intellectual content of this thesis is the product of my work and as per general norms of reporting research findings, due acknowledgements have been made wherever the research findings of other researchers have been cited in this thesis.

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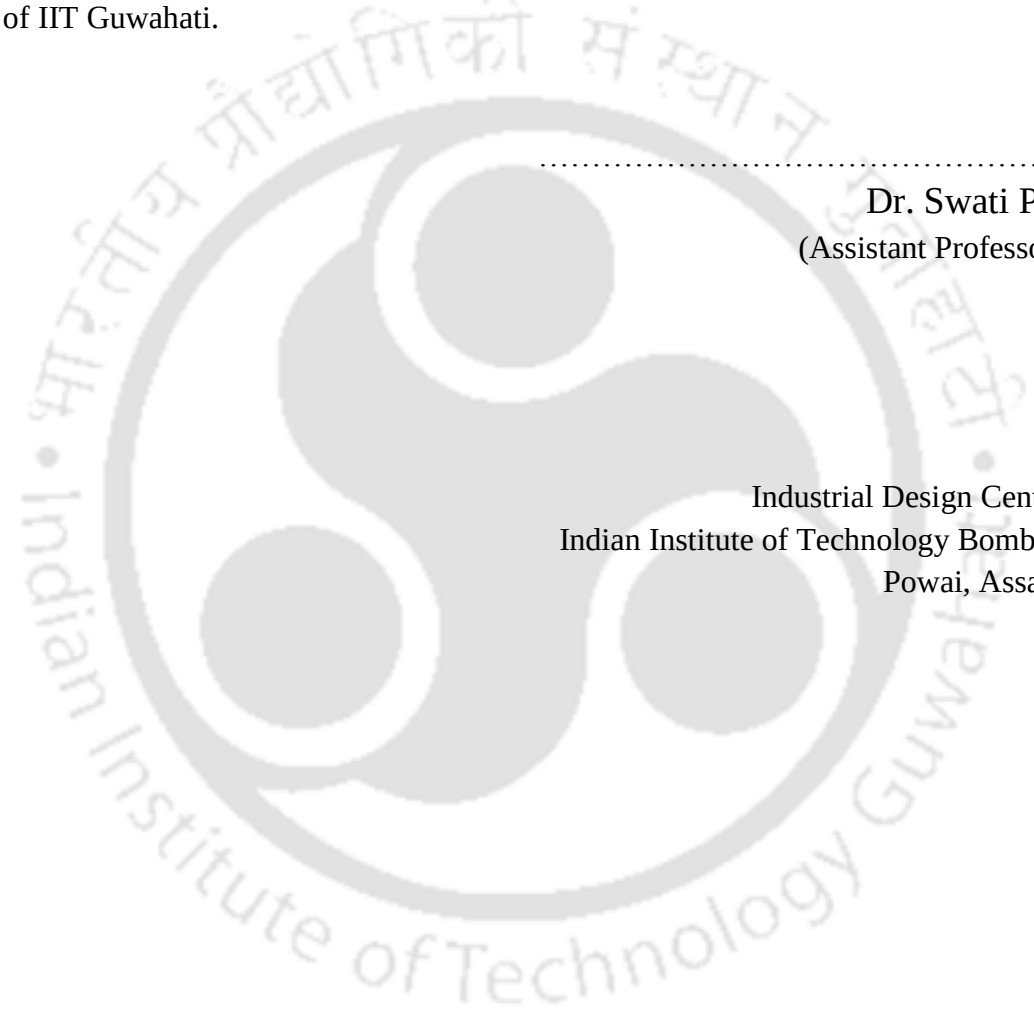
CERTIFICATE

This is to certify that the thesis work presented herein by Ms. Amrita Bhattacharjee was undertaken under my guidance and supervision. She did not submit the volume of work presented here, for the award of Doctor of Philosophy (PhD) in Design of Indian Institute of Technology Guwahati, earlier for any other degree.

She has undergone four specified/ suggested courses and fulfilled all the requirements of rules and regulations as mentioned in the PhD ordinance for submitting the thesis for PhD degree of IIT Guwahati.



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Abstract

Over the past century, lighting technology has evolved from incandescent lamp to today's LED technology. Following the advancement there is an increased emphasis on perception based lighting design in exhibition spaces. It has been identified that most of the studies on lighting in art galleries have given importance to the technical and economic aspects of lighting. However, the viewers' perception and preference on lighting conditions has gained relatively less attention in this context of regard. The current lighting design practice in art galleries is based on some canonical rules that scarcely represent perception of viewers for viewing artworks. A key dilemma for research in this area is that different professionals are associated in this field that lead to contradiction in views of lighting design process. In order to fulfil this gap, this thesis aims to develop a lighting design approach that will best possibly serve the expectations of different exhibition stakeholders while satisfying the visual preferences of viewers for effective spotlight design in art exhibition.

The thesis has initiated by thorough literature review that helps to identify the existing research gap and to construct hypotheses. After identifying the research gap, the study has progressed through two main phases. In first phase, a field study was carried on to understand the lighting scenario for painting exhibition in Indian art galleries. A lighting survey in art galleries of India was conducted to reveal the existing lighting conditions. Successively, structured interviews with professional painters were conducted to explore their views on lighting on paintings. In continuation, interviews with different exhibition stakeholders were conducted to understand the lighting design process that is presently being followed in art galleries of India. The field study along with the literature review enables to identify the key lacuna in this area of study.

In second phase a set of laboratory-based experiments were conducted to verify the hypotheses. Qualitative as well as quantitative approaches were taken to carry out these experiments. For each experiment, qualitative study was done on 30 participants by using questionnaire on semantic differential scales, whereas, quantitative study was done on 10 participants by using eye-tracking method. The response of the participants were statistically analysed to explore the significant effect of light parameters on perception of viewers. These findings from the experimental results show that different lighting parameters considered in this study have significant effect on viewers' perception while viewing paintings. Successively, an experimental study was carried on to understand the visual preferences for effective spotlight design in painting exhibition. Based on the results of this experiment, a lighting design approach has been developed for effective spotlighting in painting exhibition from viewers' perspective.

The study provides an insight for selecting spotlight for painting exhibition based on visual preference. Moreover, it tries to bridge the gap among the different stakeholders associated with exhibition design. The exhibition stakeholders can develop lighting design based on the findings of this study related to the effect of lighting parameters on visual perception. The novelty of the present study lies in the elicitation of a design approach that incorporates light as a design element in the early stage of exhibition design process. The purpose of this study is not to restrict but to emancipate lighting design for art galleries from specific guidelines and to optimize lighting conditions in painting exhibition from viewers' perspective.

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Glossary of Terms*

- **Correlated Colour Temperature (CCT):** It refers to the color appearance of the lighted source and is designated in kelvin (K). In interior spaces, a light source will create a "warm" environment if its CCT is about 3000 K or lower, and a "cool" environment if it is 5000 K or higher. A CCT between these two is considered neutral.

- **Illuminance:** The concentration of luminous flux falling on a surface, that is, the incident flux per unit area, is called Illuminance and is designated in lm/m^2 or lux (lx). It refers to the quantity of light falling on a surface.

- **Spectral Power Distribution (SPD):** It approximates the perceived brightness of a light source.

***Terms are described following the IESNA LIGHTING HANDBOOK. 9th Edition, IES, 2000.**

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
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Chapter 1
Introduction

আমারই চেতনার রঙে পান্না হল সবুজ,
চুনি উঠল রাঙা হয়ে।
আমি চোখ মেললুম আকাশে,
জ্বলে উঠল আলো
পুবে পশ্চিমে।

--- রবীন্দ্রনাথ ঠাকুর (Rabindranath Tagore)

[With my senses hues/ Emerald as green I muse/ And the Ruby as red/ As my sight I spread/ The sky is luminous/ East to West with light glorious"](Translated by Rajat Dasgupta, http://globaldiplomat.blogspot.com/2006/11/tagores-poem-ami.html)

The verses of Tagore express the true nature of visual perception. It evokes the philosophy of subjective truth. The verses symbolize that appearance of the metaphysical world is not eternal but a judgmental one. It depends on how human beings perceive it. Even light will be meaningless if we cannot experience it through our senses. The phrase 'As my sight I spread' is an abstraction of the true realization of our visual cognition. It symbolizes the relationship between physical light and human perception. It allows us to correlate our senses with surroundings and to express our perceived world through the cognitive mind. The expressiveness of the infinite joy of universal integration finds its own way in the Literature, Architecture, Painting, and Music [1]. Thus, painting is nothing but a mixture of lines and colours until viewers perceive it with artistic sense. Similarly, the light effect on a painting is merely a physical phenomenon until viewers perceive its pleasantness and express their preferences.

Over the past century, numerous paradigm shifts have occurred in the lighting industry including gas lighting, incandescent lamps, fluorescent and high-intensity discharge lamps, solid-state lighting and more [2]. However, light is still considered as an intrinsic property of the light source and not an intrinsic property of visual perception. The conciliation of light and perception makes the appearance of visible things differently.

1.3 **Points of Departure**:

Exhibition is a collection of objects such as work of art that exhibit to the public [3]. Light plays a crucial role in spatial impression and enjoyment of art [4]. Artwork can be regarded as an artefact that has been crafted to interact with light. An artist who applies paint to canvas is adding pigments those are able to absorb select bands of the spectrum of incident light and can modify the spectrum of reflected light [5]. Visible light is part of the electromagnetic spectrum and is the range of wavelengths that are

detectable to the human eye [6]. The visible spectrum when focused upon the retina, the absorbed energy of the photons stimulates the retinal photoreceptors and causes a sensory response in the visual cortex of the brain. This property distinguishes light from all other types of radiation, and it is a very narrow wavelength band ranging from 380 to 760 nanometers (nm) [5]. Human vision and perception of the surrounding world are strictly dependent on the way brain interprets and stores the received information [7]. In many ways, eyes are merely an extension of the human brain and the impulses that they provide influence the feelings of human beings [8]. The visual feeling interacts with lighting has a significant effect on how human perceive anything. The eye has the ability to perceive things under different light levels through visual adaption [9]. In order for a human to see an object and its details in museum or gallery environment, lighting design needs to assess the viewers' interaction with the exhibits by considering the visual adaptation. There are limits to the range of light levels that the eye can adapt to at any one time [10]. Exhibition areas where brightness is too high will cause glare that makes difficult to see the exhibit. Therefore, the amount of light falling on the surface of exhibits and the difference from one light level to another is a significant factor in exhibition lighting.

In exhibition space, light can be used as an influential tool to define the atmosphere for viewing art [11]. Visitors in art exhibition want not only to see the object, but also to gain an understanding of its nature and the artist's intention in creating it. The nature of the lighting is inseparable from the visual experience of art [5]. Lighting design achieves composition and understanding visual aesthetics by layering light in exhibition space [9]. Different layers work together to create a cohesive design [12]. In museum/ art gallery lighting design, ambient layering is used for overall room illumination whereas task layer is used to perform work. To emphasize artworks in exhibition, focal layers are used. The main idea behind focal lighting is to draw attention to the object or detail and not the light itself. In exhibition, a spotlight is used to identify a painting on which attention is to be focused [13]. Similar to a projector that focuses on the principal actor on stage in theatrical productions, the focus of a spotlight is placed on the specific individuality of the art in the exhibition [11]. It helps to create a dramatic atmosphere for the presentation of art.

Exhibition lighting design in art gallery differs in some important aspects from many other types of lighting design. Exhibits in art exhibition are often unique in size, shape, texture, colour and many are extremely sensitive to light damage [14]. In the case of painting exhibition, light damage is a vital factor to be considered. So, most of the works in this regard has put much emphasis on technical issues of the light design such as distribution, intensity, light-induced damage or luminaire positioning [15] so that light damage can be reduced. Follow of these technical pieces of advice without considering viewers' preference leads to the endless amount of monotonous lighting design in gallery spaces [16], which is not desirable. It has been claimed that in the process of exhibition design, research on visitors' experience is often neglected [17]. In practice, design decisions are taken based on intuition and assumptions made about visitor needs,

rather than being grounded in research [18]. Similarly, despite the high level of activity in the museum or gallery lighting design, relatively little attention has been given to rigorously determining the status of exhibition lighting [19]. Most of the visitor responses in this regard have been inferred based on informal reviews rather than tested empirically [20]. This limited insight about the light effect on viewers' perception contributes little toward promoting informed decision making or improving the quality of exhibition lighting [19]. It is acknowledged that there are rigorous studies on museum/art gallery lighting that analyses the technical aspects of light [21] [22] [23], however, a generalization with several artworks is usually not available in practice [11]. The argument is that the current lighting design practice in art galleries has been developed based on technical, functional, and economic values of lighting [2] that frequently omit the viewers' perception. The effective lighting for art exhibition must balance exhibition and conservation needs and enrich the viewer's experience [14]. With the rapid development in lighting technologies, there is an opportunity to shift the focus of the current philosophy of lighting design, from providing a functional, economic value to light based on visual preferences. The advancement of light emitting diode (LED) technology enables the light spectrum to be modified and colour temperature to be adjusted with the need of presentation [24] [25]. It provides a range of colour temperatures those were not available with conventional light sources. Taking advantage of this new technology, the study on lighting design in art galleries need to focus on the effect of light parameters on viewers' perception and to derive a lighting design practice that will satisfy the visual preferences of the viewers.

The display of artworks with spotlight requires an extensive design process as it involves professionals from different fields [26]. The exhibition stakeholders (such as curators, architects, conservators, lenders and lighting professionals) and artists, as well as, visitors often have different expectations about how art should be appropriately displayed [11]. Hence, effective spotlight design for exhibition needs to balance between the expectations of stakeholders and artists while bridging the gap among the different exhibition stakeholders. It requires developing a lighting design approach that will take account interest of artists and serve the exhibition stakeholders with a general approach for effective lighting design in art exhibitions.

Concisely, this study aims to investigate the effect of the spotlight on the perception of viewers and to explore the lighting preference of viewers in the context of painting exhibition. In consequence, the study aims to develop a lighting design approach based on visual preference for effective spotlight design in painting exhibition. With Tagore's perspective of the visual world, this thesis progresses to shift the exhibition lighting design process from a technical perspective to designing for viewers.

1.4 **Outline of Thesis:**

The study has progressed through various steps that are outlined below. It provides an overview of the study phases such as literature review, field study, testing of hypotheses and experimental findings that lead to conclusions of the study. A methodological section extensively describing the procedure of each study phases have been included. It makes the study more comprehensible to the other researchers. The thesis structure is outlined below.

The thesis begins in Chapter 2 with a review of literature related to light and perception with a particular emphasis on painting exhibition. It introduces the research problems, research questions, aims and objectives and frames hypotheses.

Chapter 3 discusses the methodology that has been followed to address the research questions. It illustrates the steps for the development of whole thesis work. It elaborates the approach used to understand the light effect on visual perception including analysis method for visual perception. It describes the subsequent development of scaling factors related to the light effect on visual perception. Based on this, experimental design for testing hypotheses has been built on.

Chapter 4 summarizes the field study in art galleries and interviews with the painters and exhibition stakeholders. It reflects the existing lighting scenario in selected art galleries of India and identifies the lacuna in existing lighting scenario. It reveals some key aspects of practical need of this present study by analyzing the interviews with professional painters and exhibition stakeholders such as exhibition designers, curators and lighting professionals. It reveals the gaps among different exhibition stakeholders that in turn affect the lighting design process.

Chapter 5, 6, and 7 describe the experimental conditions and results for verifying hypothesis 1, hypothesis 2 and hypothesis 3 respectively. The experimental results are assessed to understand the effect of different light parameters on the perception of viewers when viewing paintings.

In chapter 8, an experiment has been carried out to understand the preferred lighting combination of viewers. Finally, it draws together the results in previous chapters and assesses the viewers' preferable optimum lighting condition for viewing wide-range of paintings.

The extent and conclusions of the thesis are outlined in Chapter 9. It summarizes the key findings of the whole study. In succession, it frames a design approach to have a lighting condition in art galleries based on visual preference. The chapter discusses the implications and limitations of this present study. Finally, it ends up by proposing future research scopes that may build on inferences of the present study.

Chapter- 2
Literature Review

This chapter reviews various studies on lighting in art galleries and the studies that are associated with the light effect on visual perception. Then, the chapter considers the review of the lighting design approach that can be effective in the lighting design process in art galleries and can improve the lighting quality from viewers' perspective.

2.1 Standard recommendation on lighting in art galleries:

Art exhibition in galleries is constructed to display art and artefacts to the public [27]. Thus, lighting design for painting exhibition in art galleries should include exhibits' protection and the proper visibility level in the course of the visit. In order to cause minimal damage to light-sensitive artefacts, minimization of the exposure of the artistic production with the electromagnetic radiation is required [21] [28] [29] [30]. The International Commission on Illumination (CIE) has classified the exhibits that are usually displayed in art galleries and museums in three main categories according to their light sensitivity (Table 2.1). Following this classification, the maximum Illuminance level on highly susceptible materials is 50 lux [14]. It has been found that similar illumination level has been recommended in French and Japanese recommendations [31]. Also, according to Indian standard (IS: 3646), the maximum Illuminance to be provided on the principal plane of the highly light-sensitive object in art galleries which has been classified as same as CIE classifications is 50 lux [32].

Table.2.1. CIE recommended total exposure limits

Types of Material	Maximum Illuminance	Lux-Hours* per year
Highly susceptible displayed Materials: Textiles, cotton, natural fibres, furs, silk, writing inks, paper documents, lace, fugitive dyes, watercolours, wool, some minerals	50 lux	50,000
Moderately susceptible displayed Materials: Textiles with stable dyes, oil paintings, wood finishes, leather, some plastics	200 lux	480,000
Least susceptible displayed Materials: Metal, stone, glass, ceramic, most minerals	Depends on exhibition situation	---

* Lux-hours = Illumination Level (lux) x Number of hours/day x Days

Different studies have argued this recommended light level as enough visibility level for colour discrimination [33] [34] [35]. However, viewers' comfort for visibility has not been considered in these earlier studies. In the art exhibition, the displayed object is not merely an object to see but it is to enjoy aesthetically with a critical understanding of the art. According to famous architect Vitruvius, beauty should delight people and raise their spirits [36]. So, talking about painting exhibition, it should connect with the emotion of the viewer. According to study light is one of the important factors, which influences pleasure, arousal and domination [37] of human beings in a given space. However, this cannot be achieved by simply applying a light level that has been recommended to control damage [5]. It requires to identify the visible attributes (such as pleasantness, comfort, brightness etc.) of the displayed paintings and to select the lighting condition accordingly. With the advancement of artificial lighting technology, lighting in art galleries needs to consider viewers' preference for effective spotlight design.

2.2 Light and Visual Perception:

Any gallery or museum that exhibit, the primary function is to communicate with the viewer [38]. Keeping viewers in the center, the principles of art exhibition design must involve the human comfort zones followed by the aesthetic approach [39]. Displays in the art exhibition area must catch the eye of a viewer and hold the interest. The first impressions are important, and it must easily take in by people [40]. However, to catch the viewer's attention and to make the displayed objects appear attractive and appealing most of the lighting techniques in art galleries are derived from practices developed for merchandise displays [5]. It raises ethical questions as because the goal of a painting exhibition in art galleries is not associated with the marketising of any product. Rather, it has artistic and aesthetic values that may destroy due to merchandise lighting techniques. An optimum situation for a painting exhibition is one for which the lighting is specifically suited to the characteristics of the painting and provides for a visual experience that satisfies viewers with minimum light exposure of the painting [5].

Aesthetic judgments of any painting exhibition concern the appearance of the painting to the viewer. Judgments of artworks in the exhibition include an emotional component i.e. how space makes the viewer feel. According to some studies, this aesthetic judgment can be defined by the lighting quality of that space [41] [42]. Maintaining lighting quality is an important factor in aiding human perception that means being mindful of the type, colour and quantity of light [43] provided in a given space or on an object. These three factors can be technically defined by the three basic parameters of light: spectral power distribution (type of light), correlated colour temperature (colour of light) and Illuminance (quantity of light). So, in the case of painting exhibition, it is necessary to focus on these three factors for effective spotlight design from the viewers' perspective.

In 1941, Kruithof [44]conducted a study to reveal preferred combinations of illuminance and correlated colour temperature (CCT) for interior lighting condition. Specifically, the Kruithof graph shows lower and upper illuminance thresholds for a range of CCT that bound the region within which the illumination is considered 'pleasing'. According to

Kruithof graph, viewers will find ‘pleasing’ in high CCT illumination at high illuminance and low CCT illumination at low illuminance. In succession, it has been shown that viewer preferred warm (2800K) sources at low intensities [45].

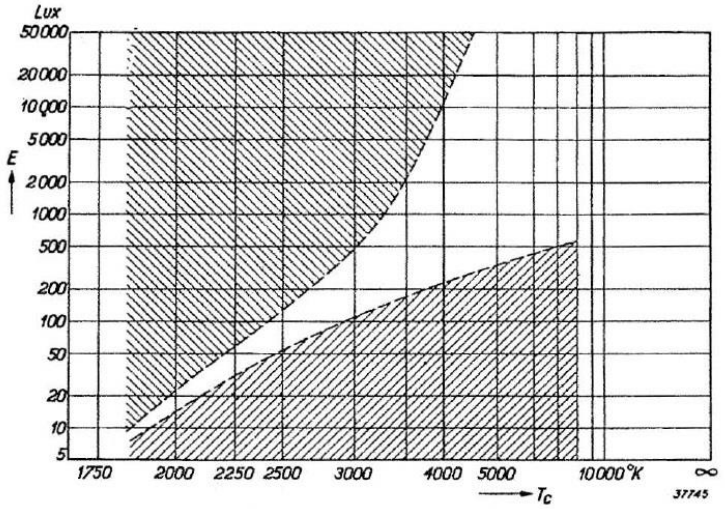

Fig.2.1. Kruithof’s Graph

The unshaded area is referred as ‘pleasing’. CCT (Tc) is presented (in K) along the abscissa and illuminance (E) is presented along the ordinate axis (in lux)

Kruithof’s experiment was pioneering, from a technological point of view and as a guide to the design of artificial lighting [46]. In spite of the fact that Kruithof’s results have gathered a lot of recognition, however, empirical support for this study is somewhat lacking [47]. In the study, there is no detail discussion about the experimental method or procedure for data analysis [48]. Several attempts to test Kruithof’s findings have been reported with inconsistent conclusions [49] [50]. Among all the studies based on validation of Kruithof graph, only one is concluding that the effect of illuminance on ratings of brightness or pleasantness is not significant [51]. Other two studies have found that CCT has no significant effect on ratings of pleasantness [52]. [53]. Several studies in this regard have refused to accept the result from Kruithof graph [52] [51] [54] [55] though some of the studies partially support this graph [46] [56]. It was concluded as high CCT at low illuminance is unpleasant but there is no such indication of low CCT at low illuminance can be considered as pleasant [46]. In these studies, it is apparent that observers made judgments regarding an illuminated space rather than looking directly at specific objects.

In 1973, Flynn et al.’s [57] studied procedures for investigating the light effect on impression and behaviour, which is a classic study in this area of interest. They categorised the light effect on human perception into three principal factors, named as ‘perceptual clarity’, ‘evaluation’, and ‘spaciousness’ [2]. The ‘evaluative’ perception mainly consisted of adjectives such as beautiful, pleasant, relaxed that describe aesthetic aspects from illumination appearance whereas ‘perceptual clarity’ seemed to be related to visual perception of brightness. The third dimension, ‘spaciousness’ provides information regarding impression on a large spacious room. One finding from their experiment is that human perceptions interacted with more than one factor of luminous conditions. This study illustrates the impact of light on visual perception in an interior space and the significance of light as a compositional element in interior space [58]. However, lighting effects on the

perception of viewers while viewing any particular object has not been considered in these studies.

In 1982, Loe et al. [59] conducted a series of experiments to understand the preferred lighting conditions for the display of paintings. They exhibited oil and watercolour paintings under fluorescent lamps and daylight. Their study showed two main factors are driving visual perception when viewing paintings. Factor 1 named as 'quality evaluation factor' is associated with pleasantness, stimulation and attractiveness and factor 2, named as 'lighting factor' refers to the brightness and starkness of the space. The experimental results of this study showed that each of the two factors with regard to the painting assessment and painting illuminance steeply rose until an illuminance of approximately 200 lux, above this illuminance the rate of increase reduced. The study also showed that at low illuminance warm colour lamps are preferred by the viewers. However, the study has not considered advanced light source such as LED as an exhibit light.

Yoshizawa et al. [60] studied the effect of LED illumination on visual perceptions of observers in a museum or gallery environment. They verified viewers' preferred lighting condition based on Kruithof's graph. Only oil paintings were considered as exhibits for this study. They found out that two principal factors i.e. 'visibility' and 'texture' were driving visual perception for viewing oil paintings. The factor visibility was associated with the pleasant appearance of paintings and the factor texture was associated with warmth appearance of paintings. The conclusion of the study has reported that the viewer's preference has a negative correlation with CCT whereas Illuminance has a positive correlation. Another study on viewing paintings illuminated by LEDs [61] has also concluded that the appearance of paintings is principally driven by two factors: 'visibility' and 'warmth'. The results of this study showed that higher CCT creates brighter, clearer and cooler visual perceptions.

An experimental study on the impact of illuminance and colour temperature on viewing fine art paintings under LED [62] conducted by Zhai et al. found out that the perceptions of 'comfort' (including scales of comfortable, natural, pleasant, relaxed, active, lively and soft) decrease with the increase of CCT. The study further concluded that compared to Illuminance, CCT had a lesser overall impact on viewing museum paintings. It shows that an increase of illuminance from 50 lux to 200 lux will sharply raise the comfort or pleasant perception of viewers but tend to show a smaller increase at 800 lux. The study has partially accepted Kruithof's graph that a higher CCT at a lower Illuminance is unpleasant but it does not imply that a higher CCT source will be more pleasant than a lower CCT source at higher Illuminance level [62]. Further, this study has concluded that Kruithof's graph may not be suitable for LED lighting for viewing fine art objects. However, another study on viewing paintings under LED illumination has agreed with Kruithof's graph [63]. So, from different studies in this regard it can be said that the acceptance of Kruithof's graph is still a debatable issue and very less study has been carried out for particularly viewing paintings. The studies are summarized in Table 2 to have a clear view on the results of these studies.

Table 2.2. Summary of studies on Kruithof's graph

Test Condition	Conclusion on Kruithof's graph	Comment
Interior illumination for particular task [56]	Partial support	Disagreement for preferred CCT
Interior illumination for particular task [46]	Partial support	High CCT at low illuminance is unpleasant but low CCT at low illuminance cannot be considered as pleasant
General room illumination [52]	Doesn't support	CCT has no significant effect on pleasantness
General room illumination [53]	Doesn't support	CCT has no significant effect on pleasantness
General room illumination [51]	Doesn't support	Illuminance has no significant effect on pleasantness
Interior illumination for particular task [54]	Doesn't support	Lowest and highest CCT conditions have lower preference
Lighting for room decor [55]	Doesn't support	CCT has no significant effect
Viewing painting [63]	Fully support	Both CCT and Illuminance are significant
Viewing painting [62]	Partial support	Higher CCT at a lower Illuminance is unpleasant but higher CCT source may not be more pleasant than a lower CCT source at higher Illuminance level
Viewing painting [60]	Doesn't support	Preference has a negative correlation with CCT but positive correlation with Illuminance

A review of the literature on Kruithof's graph has pointed out that one reason for disagreement between studies is an imprecise specification of the SPD of the light sources [47]. This specification is frequently limited to CCT. As SPD varies with the type of light, so, different type of light can have the same CCT. Therefore, specification of CCT alone does not pinpoint the precise SPD used in a study. Different studies have said that only CCT fails to predict the perceived brightness of a scene [50] [64] [65] [66] [67] [68]. Different types of spotlights are used in exhibition lighting. The incandescent and tungsten halogen [9] are dominantly used as spotlights whereas LED also has been introduced as spotlights in some gallery spaces. A study on the perception of pleasantness with two types of lamp having same CCT has concluded that the comparison of different types of lamp having different spectrum distribution with approximately same CCT showed no differences [54]. The study was done to assess preference for office lighting and it has concluded that further investigation is needed to explore fine colour perception issues to evaluate the significant effect of different light sources. Nevertheless, from the experimental result that was carried out on Japanese paintings, it was found that the subjective feeling under LEDRGB at 10 lux is almost same as with white fluorescent lamp

at 700 lux [69]. The study has shown that the LEDRGB i.e. (light source composed of red, green and blue LEDs) lighting is more effective to make chromatic objects appear to be more colourful and vivid compared to other light sources at very low illuminance level. So, it can be said from this experimental result that viewers' feelings of pleasantness may vary according to the type of light along with Illuminance. Hence, the effects of type of spotlights on viewers' perception need to be verified. Also, whether alone CCT has a significant impact on viewers' perception need to be examined.

It can be said from the literature review that, there need to have a further study regarding the Kruithof's graph and its applicability in relevance to viewing paintings. In addition, the existing recommendation standards for light level in art galleries and the types of spotlights need to be reexamined with the advancement of light sources. In the course of the literature review, reported study in India was not readily available in this context of regard as per knowledge. So, there is a need for research to have effective spotlight design for painting exhibition in art galleries of India.

2.3 Lighting Design Approach:

Light is a basic design element in the interior design that is essential for the presentation of fine arts [70]. A survey on interior design has indicated that there is a gap between the way designers communicates about light and the terminology used to discuss light [71]. In contrast to design discourse to discuss other design elements, discussion of light focused only on technical and functional issues, such as lamp technology, photometric and luminaires. Therefore, instead of using technical terminology of light (e.g SPD) it would be better to use linguistic terms (e.g. type of light) as a design approach. Educators and practitioners of design could benefit from using linguistic vocabularies as a starting point for exploring light during the early phases of the design process [58]. The potential of light as a design element is much the same way as the artist uses colour to compose a painting or a poet uses words to create emotion [71]. It means light itself has inherent characteristics that can be manipulated to enhance the visual effect. Therefore, lighting design approach in art galleries should emphasize the potential of light as a design element, moving the application of light beyond a purely functional perspective. In view with this, there is a need to frame a lighting design approach in art galleries that will help to incorporate light as a design element in the early development of design process to have optimum lighting condition from viewers' perspective.

The earlier researcher has suggested [72] that by changing light settings such as intensity and colour, designers could alter an environment's perceived brightness, pleasantness, tension etc. These findings illustrate light's impact on visual perception in an interior space and the significance of light as a compositional element in interior space [58]. However, how lighting composition modifies the appearance of an object has not been discussed. Therefore, there is a need for research to understand the light effect on visual perception while focusing on any particular object such as painting.

To improve exhibition lighting quality, designers need to understand stakeholder expectations and the problems in existing lighting conditions [19]. Stakeholders include gallery personnel (curators), designers (interior designers/ exhibition designers and lighting designers/ lighting professionals) and visitors (viewers). Effective lighting for art exhibition must balance the concerns of each stakeholders [14]. Successful lighting design essentially needs to address the priority expectations of end-users i.e. visitors. In art galleries, dominant visitors are professional or amateur painters (visual artists). Therefore, to understand the prior expectations of the viewer as well as an exhibitor, painters' opinion about lighting quality in exhibition need to know. However, in the course of the literature review, reported study in India was not readily available in this context of regard as per knowledge. Therefore, there is a need to explore the existing lighting condition in galleries and to interact with stakeholders to have a design approach for effective spotlight design in art galleries of India. [19]

2.4 Research Questions:

Based on the literature review the following research questions have been constructed.

1. What is the existing lighting scenario and design process for exhibiting paintings in art galleries of India?
2. What is the impact of different types of spotlight on viewers' perception while viewing paintings?
3. What is the effect of CCT on viewers' perception while viewing paintings?
4. What is the effect of illumination levels on viewers' perception while viewing paintings?
5. Which combination of lighting parameters do viewers prefer for viewing paintings?

2.5 Aim and Objectives:

This research aims to study visual preferences for effective spotlight design in reference to painting exhibition in Indian art galleries.

Objectives:

- To explore the existing lighting scenario and design process in art galleries through field study
- To examine the impact of different types of spotlight on viewers' perception while viewing paintings keeping all other light parameters constant.
- To study the effect of CCT on viewers' perception while viewing paintings keeping all other light parameters constant.
- To examine the effect of Illuminance on viewers' perception while viewing paintings keeping all other light parameters constant.
- To find out viewers' preferred combination of lighting parameters for viewing paintings.

2.6 Hypotheses:

To address the research questions, the following hypotheses have been framed.

- H1. Perception of viewers while viewing paintings changes due to different types of spotlight keeping other light parameters (CCT & Illuminance) constant.
- H2. Perception of viewers while viewing paintings changes due to different CCTs keeping other light parameters (type of light & Illuminance) constant.
- H3. Perception of viewers while viewing paintings changes due to different Illumination levels keeping other light parameters (type of light & CCT) constant.

To achieve research objectives, a study has been designed following the research methodology as described in the next chapter.

Chapter 3
Methodology

The lacuna identified through literature review in the previous chapter establishes several research objectives. In order to attain the research objectives, the thesis comprised a detailed study, consisting of two separate phases. The first phase aimed to explore the existing lighting scenario and design process in art galleries through field study, and in the second phase, investigations on the effect of different lighting parameters on visual perception when viewing paintings were conducted through laboratory-based experiments. Based on the findings of the two phases, a design approach has been framed for effective spotlight design in a painting exhibition in Indian art galleries. The overview of the study methodology is as shown in fig.3.1.

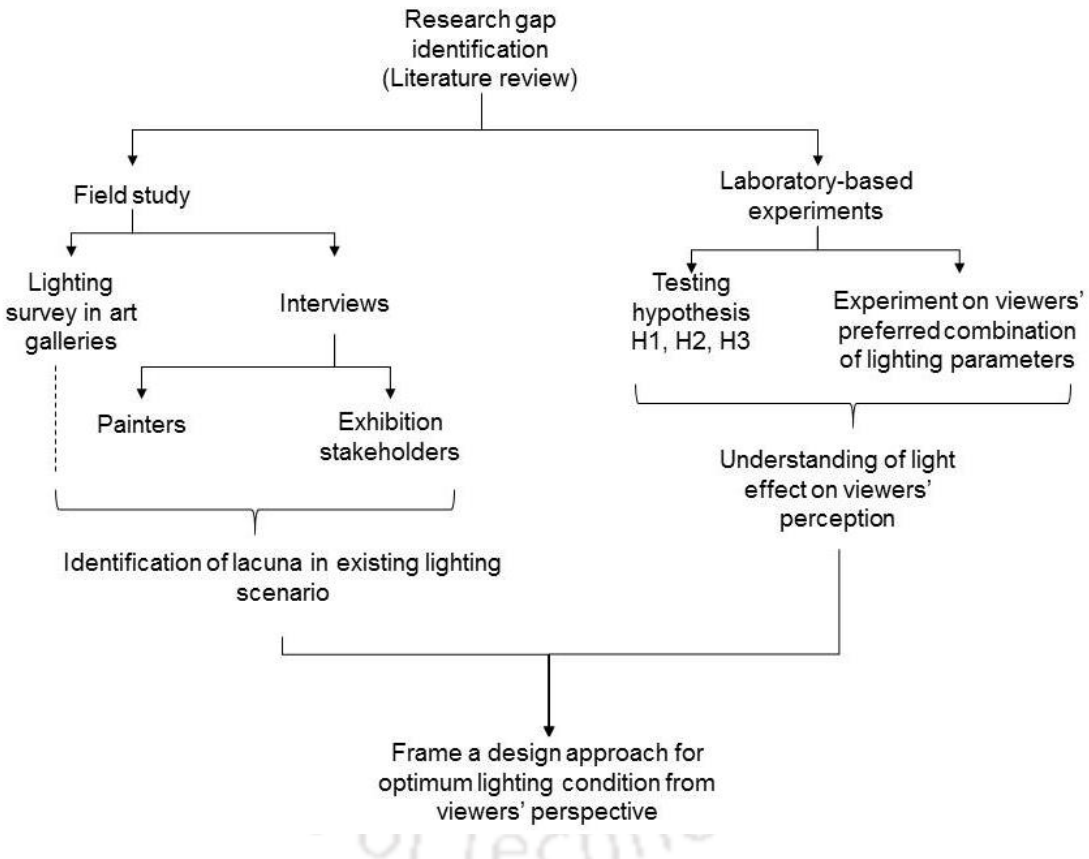

Fig.3.1. Research methodology

The study has been progressed through several steps as discussed below.

3.1 Field Study:

3.1.1 Lighting survey in art galleries:

Gallery is a discrete space in which exhibition is displayed [20]. In the case of permanent exhibitions, 'exhibition' and 'gallery' often become synonymous terms as these two are intimately linked. The galleries that have been selected for this study are

the art galleries having permanent exhibition halls and permanent lighting set up for paintings. The challenge of these galleries is to present art in an interesting and engaging way, without having the real chances to introduce the most advanced lighting strategies from time to time [16]. The physical, temporal and financial limitations usually result in a very monotonous light set up. Therefore, a survey was conducted in selected galleries of India with permanent lighting set up, to understand the present lighting conditions in painting exhibition space.

3.1.2 **Interviews:**

Interviews are a widely used tool to access people's experiences and their inner perceptions, attitudes, and feelings of reality [73]. Interviews allow in-depth analysis from relatively small sample size and help to understand the knowledge, values, beliefs or decision-making processes of stakeholders while strengthening research design and output. The various types of interviewing range from face-to-face verbal interactions to mailed or self-administered questionnaires, and telephone surveys [74]. It has a wide variety of forms that can be divided into three main categories: structured interviews, semi-structured interviews, and unstructured interviews. A structured interview is an interview that has a series of pre-established questions with a limited set of response categories. It may consist of few open-ended questions also. Hence, in structured interviews, all respondents receive the same set of questions, asked in the same order or sequence. The predetermined nature of structured interviewing is aimed at minimizing errors. The interviews generally associated with survey research are most likely to be this kind of interviews. Therefore, to understand the views of painters on existing lighting conditions in art galleries of India, structured interviews have been conducted. The set of questions for these interviews were based on some factors related to lighting design which have already been used by earlier researchers to understand lighting preference of viewers [35] [60] [62] for viewing paintings. Face-to-face interactions, as well as, survey by mail were conducted as the means of interviews. In a similar way, to understand the lighting design procedure interviews have been conducted with the different exhibition stakeholders (gallery personnel, exhibition designers and lighting professionals). For this, the set of questions was made following the questionnaire [75] made to survey on museum lighting by an earlier researcher for curators of the museum. However, the questionnaire was modified according to the research context. The interviews with the painters as well as exhibition stakeholders reveal some key aspects of the need for redesigning the lighting condition.

3.2 Laboratory-based experiments:

To understand the light effect on viewers' perception, laboratory-based experiments have been conducted. Many lighting professionals have investigated the effects of lit environment on visual perceptions for several decades [2]. In Flynn et al.'s [57] investigations for light effect on impression and behaviour, they initially obtained ratings on semantic differential scales in response to six different lighting configurations. They used factor analysis to reduce the factors in semantic differential scales to three principal components. Later, in a successive study to develop a methodology for measuring subjective impressions in lighting [76], they did an analysis of variance (ANOVA) to provide information concerning the statistical significance of

differences in mean ratings for various light settings. Studies to investigate the visual perceptions of observers in a museum or gallery environment have followed the same procedure to examine the appearance of paintings due to light effect [35] [60] [62]. Therefore, following this methodology, experiments have been designed to test and verify the hypotheses (H1, H2 and H3). Methodology for the experimental procedure is as described below.

3.2.1 Experimental Set up:

An environment close to art galleries of India has been simulated in the laboratory of Department of Design, IIT Guwahati. In this environment, paintings were exhibited under different lighting conditions. It is suggested by the earlier researcher [76] that, the experiment should be designed to eliminate or hold constant as many potentially confounding variables as possible. Only the variable (i.e. lighting) under investigation should vary from one setting to another. Hence, all the experiments have been carried out in the same laboratory to minimize the variations in thermal conditions. For simulating experiments laboratory space was partitioned to eliminate the variation in space proportion from one setting to another. The dimension of the space is shown in fig. 3.2.

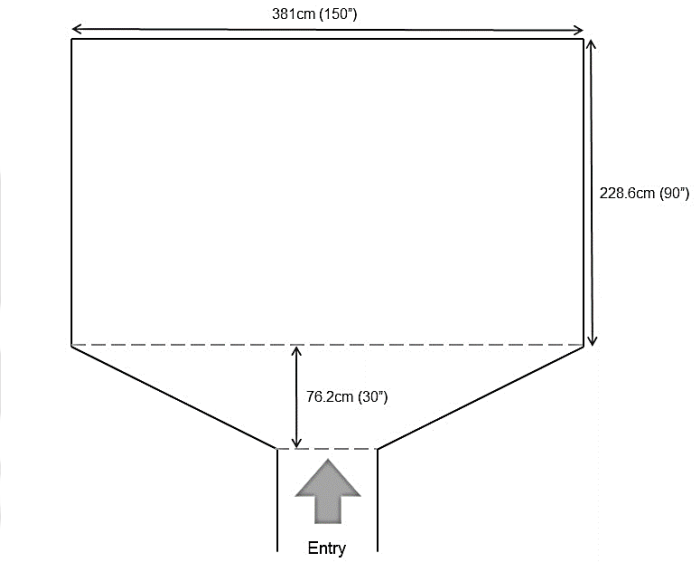

Fig. 3.2. Dimension of the experimental space

Three consecutive experiments have been conducted to understand the significant effect of each individual light variable on visual perception while viewing paintings.

3.2.1.1 Selection of Lighting Stimulus:

Earlier researcher [76] has suggested that, in laboratory presentation of environmental condition, light settings should be chosen to bracket specifically the field of variables that defines the area of study. Therefore, for each experiment

conducted to verify a particular hypothesis, only one parameter of light was variable and others were kept constant.

3.2.1.2 Selection of Paintings:

According to the CIE classification for light sensitivity of displayed materials in art galleries and museums, water-based medium comes under highly susceptible displayed materials and oil medium under moderately susceptible displayed materials [14]. Following these classification paintings from two different medium i.e. water and oil have been selected as stimuli. As this study does not focus on the detrimental effect of light on the medium of paintings, so, recommended international classification has been followed for the selection of medium of paintings. Earlier researcher [77] has argued that it would be more faithful to use real paintings and carry out a comparative study among similar paintings to understand the light effect on viewers' perception. Use of a matching or discrimination task [78] will produce converging evidence for subjective rating. For example, at a time similar paintings can be exhibited under different lighting conditions so that participants can compare among them and rate accordingly. Hence, identical paintings in terms of form and colour have been chosen to avoid any discrepancy between the stimuli from a particular medium.

3.3.3.3 Participants:

An earlier study in museum environment has shown that art specialist participants respond to artworks with more understanding and are willing to put more effort into art appreciation, whereas art non-specialists respond with less understanding and put less effort into art appreciation [79]. As for this present study, viewers must have the capability of understanding artworks, so, participants from fine arts and design background have been taken for this study. For qualitative study, total 30 participants having no colour blindness were selected for the study. Among them 12 participants were female and 18 were male. All of them belong to the age group of 25 to 35 years. Among them, eye tracking has been done on 10 participants depending on their expertise in fine arts or visual fields. Earlier studies on visual attention showed that eye tracking study can be carried out successfully with 10 participants [80]. All the participants voluntarily participated in the experiments. Consent form for participants has been shown in Appendix II.

3.2.2 Study Approach:

To understand the effect of light parameters on viewers' perception qualitative approach with a questionnaire on a semantic differential scale has been taken. Semantic differential scaling provides insight into the effect of various light settings on subjective feelings and comparative ratings delineate the differences between the light settings by providing more efficient means for collecting participant's response [76]. Therefore, a 6 point semantic differential scale consists of 14 opposite pair factors (High-Contrast/Low-Contrast, Warm/Cool, Bright/Dimmed,

Clear/Unclear, Colorful/Dull, Natural/Artificial, High-Quality/Low-Quality, Active/Negative, Relaxed/Tense, Soft/Hard, Artistic/Business, Lively/Boring, Comfortable/Uncomfortable, Pleasant/Unpleasant) have been designed. The factors have been taken following the factors that are used by earlier researchers to understand lighting preference of viewers [35] [60] [62] for viewing paintings. The word pairs are associated with the appearance of paintings and with the atmosphere of exhibition space [62]. The questionnaire is shown in details in Annexure I.

An earlier study has mentioned that [78] use of only category rating to investigate the light effect on visual perception may lead to an inconsistent conclusion. The factors in the rating scale are always subjective and different participants may interpret the terms in different ways based on their personal, social and situational factors [81]. Therefore, in this study quantitative approach has been taken to verify the result derived from the qualitative study. The approach that has been used in the quantitative study is the eye-tracking method. The earlier study on the attention of viewers revealed that eye movement is an apparent index to express the relationship between what is observed and its relevance to the viewer's interest [82]. The evidence that eye tracking is a faithful study to understand the cognitive perception of viewers comes from visual aesthetic studies for viewing art done by earlier researchers [83] [84] [85] [86] [87]. The data for eye-tracking was recorded by a sensomotoric mobile eye-tracking device (SMI ETG2 Wireless Analysis Pro). This device comes in eyeglass form, which increases the mobility of users, which in turn helps to increase the precision of recorded data. The parameter that has been considered in this experiment is gaze duration. Gaze is usually the sum of all fixation durations, which is best used to compare attention distributed between targets [88]. Data of gaze duration will help to assess which painting is drawing more attention of viewers. Therefore, in parallel to qualitative study, eye-tracking data of viewers will provide supportive evidence regarding the light effect on visual perception while viewing paintings.

3.2.3 Procedure:

Participants were asked to come to the laboratory one by one. It was requested to the participants to not to have any eye-streaming work on that particular day to avoid visual fatigue. After coming to the laboratory, there were 5 minutes resting time for the participants to be habituated with the experimental environment. Within this time, the questionnaire was explained to the participants. As the questionnaire was based on the appearance of paintings due to light effect so it was instructed clearly to the participants to not to get confused with the light effect of painting itself has. Running time of the experiment was chosen from evening onwards to nullify the effect of daylight. The study involved comparison among identical paintings exhibited at a time under different lighting set ups. This approach reduces

interaction between preference for a light set up and subject matter of the artwork [89]. Each set of experiments were divided into two steps-

First, similar water-based paintings were exhibited. Each participant was asked to see the exhibited paintings and then rank the factors in the above mentioned semantic differential scale (section 3.2.2) accordingly.

In the next step, similar oil-based paintings were exhibited and the same procedure was followed. There was no preset order for viewing paintings. Participants were free to view any painting randomly in each lighting session. Also, there was no preset time limit for viewing paintings. Fig. 3.3 shows glimpses of the experimental process.

The participants for the eye-tracking experiment were instructed to compare the light effect on paintings and to gaze at the painting to which they like to view (fig. 3.4). The instruction was given so that participants gaze on the paintings based on their visual preference and not for any other possible reason.

Fig. 3.3. Glimpses of experimental process

There was no time limit for eye-tracking. However, recorded gaze duration shows that participants have taken maximum 5 minutes for gazing in a particular light session.

Fig.3.4. Eye-tracking experiment

Participants were free to move within the simulated exhibition area. However, participants were requested to keep viewing distance from painting a minimum 60 cm to avoid shadows. In a real gallery, there is no restriction of movements for the viewers, so it has been tried to give freedom of movements to the participants as much as possible. There was no preset order and time duration for viewing paintings. Participants were free to view any painting randomly in each lighting session.

3.2.4 Data analysis:

3.2.4.1 Method for Qualitative Data Analysis:

To understand the light effect on viewers' perception, 14 factors have been clustered under principal factors using principal component analysis (PCA) technique with varimax rotation. PCA is a statistical technique that can be used to identify the number and nature of the independent components within a data set [63]. In this case, the experimental data are the observers' rating scores on semantic differential scales. By applying PCA technique 14 pair of factors can be reduced to fewer representative components. These fewer independent dimensions could be regarded as the control parameters for lighting in the painting exhibition. The naming of the principal factors depends on factor loading. Highly loaded factors indicate the nature and possible name of the principal factor [76]. T-test or ANOVA was applied to investigate the significant impact of the light variable on visual perception in painting exhibition.

3.2.4.2 Method for Quantitative Data Analysis:

The binocular gaze data of participants were recorded for the quantitative study. The recorded data were analyzed through the software BeGaze3.0. Then, the gaze duration of an individual participant for an individual set of paintings under particular light has been calculated in milliseconds. Further, the data was converted as a fraction of total gaze duration for a particular set of paintings. For example, if T_w represents gaze duration of a particular participant for water-based painting under LED light, then,

$$\mathrm{Tw} = \frac{\text{Gaze duration for water based painting under LED light}}{\text{Total gaze duration for water based paintings by particular participant}} \quad (1)$$

In this way, gaze value of participant for a particular painting illuminated under a particular light has been calculated. After that, the result has been analyzed through a comparative study between gaze data for each set of paintings exhibited under different

lighting condition. Mean value of gaze data were plotted to understand the attention distribution of viewers.

All the experiments were conducted following the above methodology. The results of the experiments reveal the light effect on visual perception while viewing paintings. Based on the results of the experiments and understanding from field survey a lighting design approach has been framed for optimum lighting condition in art galleries. The details of this study have been discussed in the next chapters.

Chapter 4
Field Study

This chapter aims to give an overview of the existing lighting condition in art galleries of India through a lighting survey in galleries, interviews with painters and with different exhibition stakeholders. The chapter presents a brief analysis of the dilemma in the existing lighting design process in art galleries of India.

4.1 Lighting Survey in art galleries:

There are several art galleries and museums exist in India among which some are very famous for painting exhibition. Paintings in most of the galleries in India are exhibited under artificial lighting condition. So, in this research, only artificial lighting condition has been considered. Following galleries/ museum of India (table 4.1) has been visited during the lighting survey based on the selection criteria (section 3.1.1) and convenience of accessibility.

Table 4.1- Name of the surveyed galleries/ museums

Location	Name of gallery/ museum
Kolkata	Rabindranath Tagore Centre, Birla Academy of Art and Culture, Academy of Fine Arts
Pune	The Monalisa Kalagram, Art2Day, Raja Dinkar Kelkar Museum
Mumbai	National Gallery of Modern Art Mumbai, Jehangir Art Gallery

The vertical illuminance at the center of the displayed paintings with the use of Luxmeter (Metravi 1332) has been measured in the course of the survey. Also, the type of light and the type of paintings have been noted down. The fig.4.1 represents glimpses of exhibition view in different galleries.

(A) Birla Academy of Art and Culture

(B) Art2Day

(D) National Gallery of Modern Art Mumbai

Fig.4.1. Exhibition view of different galleries

The survey result is presented below.

4.1.1 **Rabindranath Tagore Centre (Date of survey: 1st July, '16)**:

Rabindranath Tagore Centre (RTC), Kolkata, is a unique cultural centre of Indian Council for Cultural Research (ICCR). RTC has four art galleries where various art form including paintings is exhibited. The survey results in these galleries are as follows.

Table 4.2-Abanindranath Tagore Gallery

Type of light	Vertical Illuminance (lux)	Remarks
Tungsten Halogen (spotlight) and CFL (general illumination)	407	Type of paintings may vary in each alternate week.
	401	
	350	

Table 4.3- Bengal Gallery

Type of light	Vertical Illuminance (lux)	Remarks
Tungsten Halogen (spotlight) and CFL (general illumination)	114	Exhibition on silk was going on at the time of survey.
	160	
	530	
	345	
	315	
	155	

Table 4.4- Jamini Roy Gallery

Type of light	Vertical Illuminance (lux)	Remarks
Tungsten Halogen (spotlight) and CFL (general illumination)	370	Type of paintings may vary in each alternate week.
	297	
	702	
	950	
	565	

Table 4.5- Nandalal Bose Gallery

Type of light	Vertical Illuminance (lux)	Remarks
Tungsten Halogen (spotlight) and CFL (general illumination)	66.3	Type of paintings may vary in each alternate week.
	744	
	272	
	285	

4.1.2 **Birla Academy of Art and Culture (Date of survey: 2nd July, '16)**:

The principal objective of the Birla Academy of Art & Culture, Kolkata, is to foster the growth of art and culture with an emphasis on visual and performing arts. The Academy has three permanent galleries for exhibition among which one is exhibiting sculpture and the other two are mainly exhibiting miniature paintings. As this research is only focused on painting exhibition so, the gallery with sculpture exhibition has not been considered during the survey. The survey results are as follows.

Table 4.6- Modern and Contemporary art gallery (5th floor)

Type of light	Vertical Illuminance (lux)	Type of painting	Remarks
Tungsten Halogen (spotlight)	159.3	Brush drawing on paper	Permanent Gallery
	468	Lithograph	
	335	Tempera on silk	
	182	Watercolour on paper	
	266	Watercolour on paper	
	194	Wash paintings on paper	
	301	Lineout on paper	
	108	Gouache painting	
	227	Watercolour on paper	
	299	Oil on paper	
	318	Watercolour on paper	
	49	Watercolour on paper	
	54	Acrylic on oil linen	
	28	Oil on canvas	
	45	Oil on canvas	

Table 4.7-Traditional art gallery (3rd floor)

Type of light	Vertical Illuminance (lux)	Type of painting	Remarks
Tungsten Halogen (spotlight)	78.8	Persian miniature painting	Permanent Gallery
	103.9		
	118.6		
	103.2	Mughal miniature painting	
	85.5		
	122.1		
	234		
	115	Rajasthani miniature painting	
	78		
	149		
	380	RasikaPriya miniature painting	
	176		
	257		
	84	Ragamala miniature painting	
	330		
	109	Barah-Masa miniature painting	
	133		
	100		

4.1.3 Academy of Fine Arts (Date of survey: 3nd July, '16):

The Academy of Fine Arts, Kolkata, is one of the oldest fine arts societies in India. It consists of five exhibition galleries with same lighting arrangements for painting exhibition. Here, all the exhibitions are kept for a short period like 1-2 weeks.

Table 4.8- West Gallery

Type of light	Vertical Illuminance (lux)	Remarks
Tungsten Halogen (spotlight)	1113	At the time of survey type of paintings were wash on paper. However, type of paintings may vary in each alternate week.
	967	
	875	
	1259	
	1207	
	1288	
	1247	
	1665	

4.1.4 The Monalisa Kalagram (Date of survey: 13th December, '16):

The Monalisa Kalagram, Pune, set in the verdant Pingale Farms, wishes not only to display art but also to nurture and promote all kinds of art. It has a large gallery, which hosts art shows. The survey result in this gallery is as follow.

Table 4.9- Gallery in The Monalisa Kalagram

Type of light	Vertical Illuminance (lux)	Remarks
LED (spotlight and for general illumination)	445	Halogens as down lighter are occasionally in use.
	507	
	397	
	396	
	275	

4.1.5 Art2Day (Date of survey: 14th December, '16)::

Art2Day, Pune, is dedicated to the promotion of young artists and provides a platform for them to exhibit their work along with that of eminent artists. The Gallery has featured a wide range of well-known painters, sculptors and Folk Artist to students of art colleges. The survey result in this gallery is as shown below.

Table 4.10- Gallery in Art2Day

Type of light	Vertical Illuminance (lux)	Remarks
Tungsten Halogen (spotlight)	1863	At the time of survey, water-based paintings were exhibited. However, type of paintings may vary in each alternate week.
	1782	
	413	
	902	
	989	
	621	
	636	
	1780	

4.1.6 Raja Dinkar Kelkar Museum (Date of survey: 14th December, '16)::

Raja Dinkar Kelkar Museum, Pune, a rare anthology of Indian artifacts that varies from every day artefacts like bowls, combs to musical instruments, miniature paintings, ancient dwellings etc. It has several collections of priceless artefacts among which one exhibition place consists of miniature paintings. Therefore, the survey has concentrated only that part of the museum.

Table 4.11- Miniature painting gallery

Type of light	Vertical Illuminance (lux)	Type of painting	Remarks
LED strip light (Warm)	95.7	Miniature painting on paper	Permanent Gallery
	64.6		
	64.5		
	90.1	Miniature painting on paper	
	56.8		
	46.3		
	87.6	Miniature painting on paper and cloth	
	76.2		
	54.9		

4.1.7 National Gallery of Modern Art Mumbai (Date of survey: 16th December, '16)::

National Gallery of Modern Art (NGMA) Mumbai was established with the objective of promoting modern art in the country. It has three floors to host various exhibitions and art collections of famous artists.

Table 4.12- Illumination in NGMA Mumbai

Type of light	Vertical Illuminance (lux)	Type of painting	Remarks
LED (warm) as spotlight, CFL (warm) and fluorescent tube (cool) for general illumination	175.1	Water-based painting	These measurements have taken in 1st and 2nd floor of NGMA Mumbai. The lighting design in 1st and 2nd floor is similar.
	166.4		
	74		
	162.3	Oil painting	
	39.7		
Tungsten Halogen (spotlight)	33.5	Water-based paintings	Measurements have taken in 3rd floor of NGMA Mumbai.
	59.0		

4.1.8 Jehangir Art Gallery (Date of survey: 17th December, '16)::

Jehangir Art Gallery, Mumbai, is a depository of contemporary art. It has four halls for exhibitions of visual arts i.e. the Auditorium Hall, three Exhibition Gallery, Hirji Jehangir Gallery and Terrace Art Gallery for Photography and Visual Art. Survey of lighting design has been done in three Exhibition Gallery as follows.

Table 4.13- Exhibition Gallery

Type of light	Vertical Illuminance	Type of	Remarks
Tungsten Halogen (spotlight)	373	Water-based paintings	Measurements have taken in 1st Exhibition gallery.
	372		
	366		
	467		
	401		
	439	Oil paintings	
	435		
	403		
	391		
	356		
	442	Water-based paintings	Measurements have taken in 2nd Exhibition gallery.
	368		
	426		
	486		
	317	Oil paintings	
	405		
	470		
	404		
	444	Water-based paintings	Measurements have taken in 3rd Exhibition gallery.
	436		
	422		
	480		

4.1.9 **Findings**:

The survey result depicts the present lighting scenario of art galleries in India. Fig 4.2 shows the mean illumination levels with respect to each art gallery. From the figure, it can be observer that the illumination level has no particular level or limit within which the paintings are displayed. Also, any standard recommendation [14] [32] for lighting level (table 2.1) in art galleries has not been followed in these galleries (referred to table 4.2, table 4.3, table 4.4, table 4.5, table 4.6, table 4.7, table 4.8, table 4.9, table 4.10 and table 4.11). Overexposed lighting design technique with Halogen as spot light has been used which is a kind of merchandise lighting techniques [5] arising ethical question for painting exhibition (referred to table 4.8 and table 4.10). Only in Raja Dinkar Kelkar Museum, (table 4.11) lighting level has been tried to keep in a certain limit from the aspect of preservation. Also, LED has been used to restrict damage to the paintings. In case of Jehangir Art Gallery (table 4.13), though the light level is maintained within a certain range but as a whole lighting design is not based on viewers' perception.

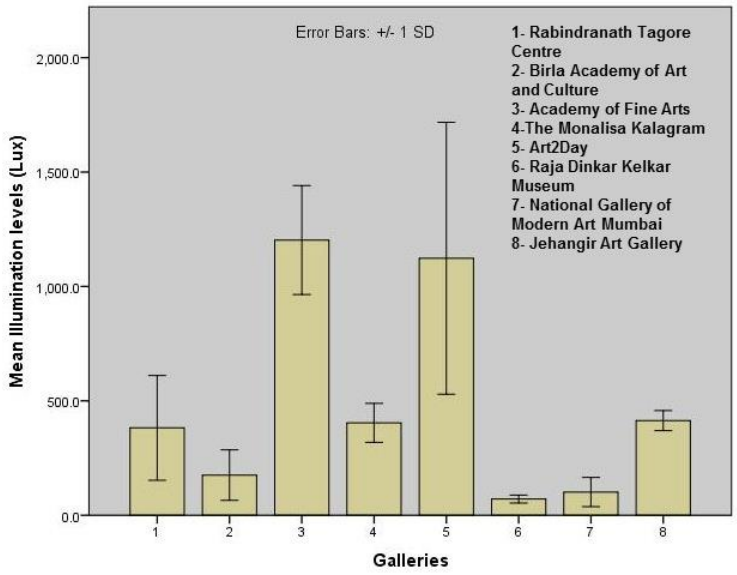

Fig. 4.2. Mean illumination levels w.r.t. each gallery

It has been noticed that in art exhibition, dominant viewers are painters/ visual artists. In next segment, interviews with professional painters/ visual artists of India have been summed up in order to understand their lighting preferences for painting exhibitions.

4.2 **Views of painters on lighting conditions in painting exhibition:**

To understand the preferred lighting condition of painters/ visual artist for painting exhibitions interviews with ten professional painters/ visual artists across India has been conducted. The interviews were conducted following the methodology as discussed in the previous chapter (chapter 3). The detail interviews are mentioned in Annexure III. The key findings from the interviews are discussed below.

- **Low-contrast/ High-contrast:** Most of the painters (9among 10 painters) have preferred low contrast light over high contrast light for their painting exhibitions.

- **Cool/Warm:** While it was asked that which colour temperature of light the painters prefer for exhibiting their paintings, most of them (7 among 10 painters) selected cool over warm light.

- **Dimmed/Bright:** About the brightness of light most of the painters have chosen low brightness (8 among 10 painters) i.e. dimmed light over bright light for a painting exhibition.

- **Artificial/ Natural:** While it was asked that under which kind of light effect painters like to exhibit their artworks then most of the painters (8 among 10 painters) preferred light similar to natural light than artificial light effect.

- **Hard/Soft:** About the intensity of light on paintings all the interviewed painters preferred soft lighting for their exhibition.

- **Merchandise/Artistic:** Whether lighting design should make a merchandise atmosphere for promoting the artworks or should create an artistic atmosphere for the painting exhibition is a philosophical question to deal with. At this point, most of the painters (9 among 10 painters) preferred artistic atmosphere.

Interviews with painters suggest that lighting design in the art gallery should create a pleasant atmosphere that will accompany the mood of the exhibition. According to the painters at present condition, there is 'lack of proper thinking' regarding lighting design in art galleries. In addition, painters have suggested replacement of Halogens that are in use in galleries with LEDs because of its colour adjustability. The painters expect to have a combination of yellow and white in exhibition spotlight. So, it can be said that if lighting variation is not possible then the CCT should be fixed in between extreme cool and extreme warm. However, none of the surveyed galleries is providing this kind of lighting atmosphere. Therefore, there is a necessity to research for effective spotlight design in art galleries based on the perception of painters who are the dominant viewers in an art exhibition.

4.3 **Views of exhibition stakeholders on lighting design process in art galleries:**

To understand what factors are practically considered in the lighting design process in an art gallery, interviews have been conducted with ten exhibition stakeholders following the methodology as mentioned in the previous chapter (chapter 3). The detail interviews with exhibition stakeholders are mentioned in Annexure IV and Annexure V. The key findings from the interviews are summarized below.

- **Followed guidelines/ considered factors**: In the course of lighting design in art galleries, curators prefer light sources with lower damage potential considering the betterment of visual appearance of artefacts. Most of the curators do not follow any standard guidelines or recommendations for lighting installations, whereas, lighting professionals have preferred to follow standard recommendations for lighting design in art galleries. Also, lighting professionals have valued energy-efficient lighting design which is not considered by curators.

- **Predominant light sources**: Most of the curators have selected LED and Halogen as predominant light sources presently are in use in galleries. In contrary, lighting professionals have selected mainly Halogen as existing predominant light sources. It is noticeable that few lighting professionals have chosen LED as a new trend in exhibition lighting.

- **Lighting design according to exhibited artworks:** From the interviews, it is interesting to notice that lighting professionals have mentioned that lighting design does not change according to exhibited artworks. If it changes also, then it only depends on the theme of the exhibition. In contrary, curators have mentioned that lighting design is modified based on the material composition of artwork, colour composition of artwork and theme of the exhibition.

- **Considered lighting parameters**: Most of the lighting professionals have considered all the lighting parameters i.e. SPD, CCT and Illuminance, whereas, curators have focused only on CCT for the visual appearance of artefacts. Nevertheless, few curators have considered the type of spotlight also for the betterment of visual appearance of artworks.

- **Visual assessment of the lighting design:** All the interviewed curators have mentioned that they have done visual assessment of lighting design by visitors, artists and/or lighting professionals. In contrary, lighting professionals have mentioned that there is no visual assessment of lighting design. Only, one lighting professional has mentioned that there is visual assessment by gallery staffs which helped to improve proper beam angle and CCT. Also, routine maintenance work was reduced due to prior assessment of lighting.

- **Choice of light source**: When it was asked that which kind of light source is preferable for an art exhibition, then, curators, as well as, lighting professionals have chosen LED. One of the curators has mentioned that as LED provides good colour rendering so it is visually comfortable for displaying artworks. In addition, one of the lighting professionals has mentioned that LED having prominent beam angle, various CCT and improved colour rendering with less power consumption is recommendable for an art exhibition.

- **Process of lighting design**: From the interviews, it can be seen that curators have prioritized comfortable visual display. According to one of the interviewed curators, there is a common practice in Indian galleries to put up an overall generic light. This implies light design is not significant enough for many galleries. It is worthy to mention here that at present economic scenario; most of the galleries are not able to change their lighting set up according to the theme of the exhibition. Therefore, the curator has suggested that converting from tungsten halogen to LED can give an expensive yet one-time solution to this need to rationing. In addition, one of the lighting professionals has mentioned that the CCT of the luminaires should not change over time and for this LED sources with colour stability is suitable as exhibition light. However, in the process of lighting design, lighting professionals have emphasized mainly on CCT. Combination of different light parameters to achieve viewers comfort or pleasantness has not been considered.

The findings from the interviews with different exhibition stakeholders reveal that there is a dilemma regarding the lighting design process in the exhibition. The curators prefer to present a comfortable visual display. However, the tendency to overlook the effect of technical parameters of spotlights on visual perception leads to a random selection of light sources. On the other hand, lighting professionals prioritize technical and economic issues of lighting such as recommended guidelines, colour stability, energy-efficiency etc. that frequently overlook the viewers' preference. Therefore, to mitigate this dilemma, there is a

need to have a design approach for lighting design in exhibition that will best possibly serve the requirements of different exhibition stakeholders. To understand the effect of spotlights (i.e. different light parameters) on the perception of viewers, experiments have been carried out. The outcome of the experiments will help to build up a lighting design approach based on visual preferences as discussed in the next chapters.

Chapter- 5
Testing of Hypothesis: H1

As described in chapter 3, in the second phase, laboratory-based experiments have been carried out to understand the effect of different light parameters on visual perception while viewing paintings. The experimental results and findings are explained in the following four chapters.

From lighting survey in art galleries (chapter 4) it has been seen that most of the galleries are using Halogen light as a spotlight. Again, from the interviews with the painters (chapter 4) it is revealed that there is a need of research on which type of spotlight is preferable by the viewers. Also, from the literature review (chapter 2), it is revealed that very less study have considered the effect of different types of spotlight on viewers' perception for viewing artworks. Therefore, to verify H1, a study has been designed to examine specifically the effect of different types of spotlight on visual perception at the time of viewing paintings keeping CCT and Illuminance constant.

5.1 Methodology:

A laboratory space was partitioned to simulate this experiment. In this environment, paintings were exhibited under different types of spotlight keeping CCT and Illuminance constant. Fig. 5.1 illustrates the top view of the partitioned place and the placement of paintings and light sources in that simulated area.

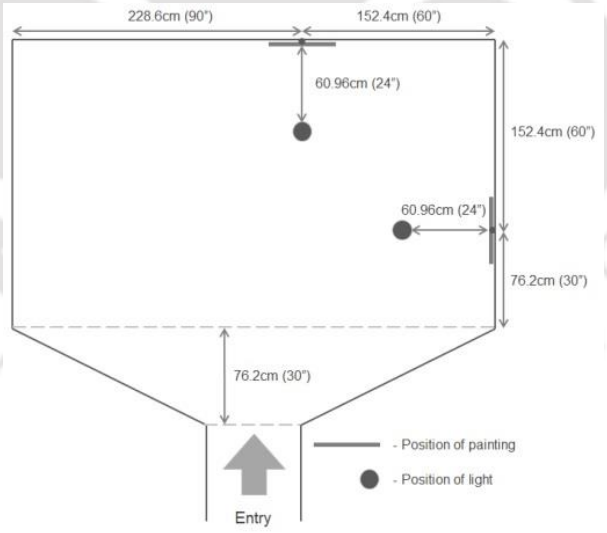

Fig.5.1. Top view of simulated exhibition space (not in scale)

As described in chapter 3, qualitative as well as quantitative approaches have been taken to understand the effect of different types of spotlight on viewers' perception while viewing paintings.

5.1.1 Experimental design:

5.1.1.1 Types of paintings:

Two identical water-based paintings (11”×14”) and two identical oil-based paintings (11”×14”) drawn by professional painters have been chosen as stimuli. From a particular medium identical paintings have been chosen to avoid any discrepancy between the stimuli. One sample of each type of painting is as shown in fig. 5.2, whereas, fig. 5.2(A) shows the sample of water-based paintings and fig. 5.2(B) shows the sample of oil-based paintings.

(A) (B)

Fig.5.2. Samples of exhibited paintings

The theme of the paintings was not specified to the painters as because in a real gallery exhibition, paintings based on any theme can be exhibited.

5.1.1.2 Types of spotlight:

As it is evident from field survey in different galleries that most of the galleries are using Halogen light as spotlight hence, Halogen of a standard commercial company has been chosen as one variant for different types of spotlight. LED of the same company has been chosen as another variant for different types of spotlight because of its comparatively less detrimental effects on paintings than other conventional light sources [23]. Also, LED is more energy-efficient than other conventional light sources and spectrum quality of LED can be easily modulated. Referred to earlier studies [35], [90], [62], for this experimental purpose a lower CCT with lower illuminance has been selected. For both the lamps, the illuminance level on the paintings was kept at 50 lux as per the standard recommendation of CIE [14] as well as Indian standard (IS: 3646) for maximum illuminance to be provided on the principal plane of the highly light-sensitive object in art galleries [32]. Measurements of vertical Illuminance has been taken on center point of the plane of the exhibited paintings with standard Luxmeter (METRAVI 1332). The value of the light level on the plane of paintings was controlled by varying the voltages through Variac (1-phase/ 0 to 270V AC / 1A). CCT for both the lamps was kept constant at 3000K, matching with the CCT of standard Halogen lamps that are in use in the galleries of India.

The experiment has been carried out following the study approach and procedure described in chapter 3.

5.2 Results:

5.2.1 Effect of types of spotlight on viewers' perception for water-based paintings:

To understand the effect of two types of spotlight on water-based paintings 14 factors have been clustered under principal factors. Table 5.1 shows the result of factor loadings with total variance explained in parenthesis for water-based paintings. From the result, it can be seen that all the factors can be explained through three main factors. Among these three principal factors, factor 3 is defining only 8.308% of the total variances. So, it can be ignored with respect to factor 1 and 2. Factor 1 can be named as 'pleasantness' which represents the atmospheric perception of lighting to the viewers while viewing paintings. It includes factors such as clear, colourful, natural, high quality, active, relaxed, soft, lively, comfortable, and pleasant. Factor 2 can be named as 'warmth' that provides information about the appearance of paintings to the viewers under certain lighting condition. It includes factors like high contrast and warm. Based on PCA result, t-test has been done only to factors defining pleasantness and warmth to understand the effect of two types of spotlight on viewers' perception. The result is summarized in table 5.2.

Table 5.1- Rotated Component Matrix of Factor analysis (water-based paintings)

Factors	1(43.584%)	2(12.977%)	3(8.308%)
high contrast	.142	.761	-.135
warm	.135	.619	.292
bright	.026	-.055	-.867
clear	.509	.021	-.574
colourful	.779	.059	-.232
natural	.509	-.378	-.111
high quality	.764	.191	-.179
active	.817	.150	-.066
relaxed	.518	-.535	-.061
soft	.443	-.559	.265
artistic	.389	-.450	-.023
lively	.927	.155	.124
comfortable	.863	-.168	.105
pleasant	.757	-.210	.053

Table 5.2- t-test results for effect of spotlights on viewers' perception (water-based paintings)

Factors	F-value	p-value
High contrast*	.126	.034
Warm*	.292	.000
Clear*	5.939	.008
Colourful	3.173	.340
Natural	.207	.486
High quality	.538	.353
Active	1.388	.486
Relaxed	.846	.117
Soft	.040	.450
Lively	1.649	.374
Comfortable*	.053	.009
Pleasant*	1.159	.009

*indicates that the factor is statistically significant ($p<0.05$)

The t-test result shows that type of spotlight had a significant impact on five factors such as high contrast, warm, clear, comfortable and pleasant. Rest of the factors in table 5.2 is not statistically significant. So, combining the results of factor analysis and t-test it can be said that type of spotlight has a significant effect on the warmth feeling of viewers while viewing water-based paintings. The pleasant feeling of viewers is also significantly associated with the type of spotlight under which paintings are exhibited. Therefore, as hypothesized in H1, the perception of viewers while viewing water-based paintings significantly changes due to the type of spotlight.

5.2.2 Preferred type of spotlight by participants for water-based paintings:

The participants have considered the effect of Halogen on water-based painting having more 'high contrast' (WP_H=4.13±1.358) than the effect of LED on water-based painting (WP_{LED}= 3.40±1.248). Similarly, participants have felt Halogen (WP_H=4.37±1.159) as more 'warm' than LED (WP_{LED}=2.73±1.258). In the case of 'clear', painting under LED (WP_{LED}= 5.13±0.819) is more clear than under Halogen (WP_H=4.43±1.135). Similarly, for the factor 'comfortable, participants have preferred LED (WP_{LED}=4.73±1.048) over Halogen (WP_H= 3.97±1.159). The participants have experienced more 'pleasant' to view paintings under LED (WP_{LED}=4.83±0.950) than under Halogen (WP_H=4.10±0.950). So, the water-based painting under LED has appeared to be low contrast, less warm, clearer, comfortable and pleasant than the paintings under Halogen to the viewers.

To support and verify the result derived from this qualitative study, the gaze duration of viewers has been analyzed statistically. Fig. 5.3 represents the plot of gaze data for water-based paintings exhibited under two different light sources. From the figure, it is obvious that the mean value of gaze duration for water-based painting under LED (M_{LED}=0.57, SD=0.061) is more than mean value of gaze duration for water-based painting under Halogen ($M_{Halogen}$=0.44, SD=0.061). So, viewers have given more attention to water-based painting exhibited under LED than the painting exhibited under Halogen. It depicts that though both the paintings

were identical but viewers have perceived it differently due to the effect of light. Therefore, in accordance with the result derived from the qualitative study, this result also revealing that the perception of viewers while viewing water-based paintings changes due to different types of spotlight as hypothesized by H1.

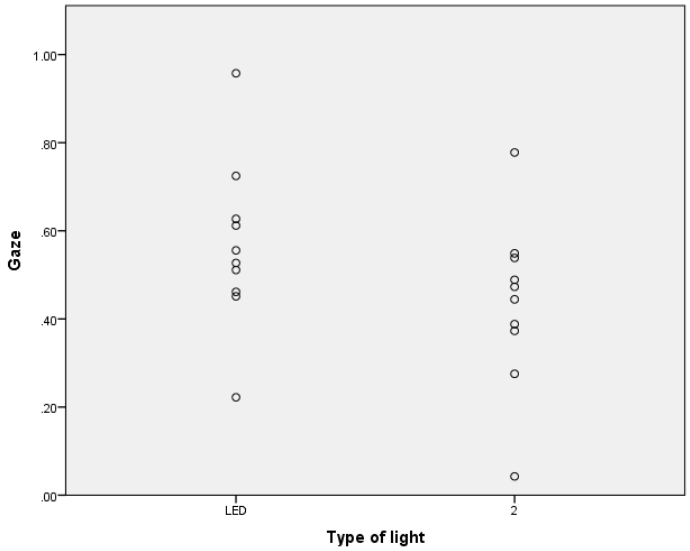

Fig.5.3. Plot of gaze data for water-based paintings

5.2.3 **Effect of types of spotlight on viewers' perception for oil-based paintings:**

To understand the effect of two types of spotlight on oil-based paintings similar statistical analysis method has been followed. Table 5.3 shows the result of factor loadings with total variance explained in parentheses for oil-based paintings. It can be seen from the table that among four principal factors, factor 1 and factor 2 explains 37.472% of variances and 13.954% of variances respectively. So, compared to factor 1 and 2, factor 3 and 4 are ignored. Again, factor 1 and 2 can be named as 'pleasantness' and 'warmth' respectively. Similar to the previous result in this case also pleasantness includes factors such as natural, active, relaxed, soft, comfortable and pleasant. Whereas warmth includes factors like high contrast and warm as well. T-test has been done on extracted factors from PCA to verify the impact of the type of spotlight on viewers' perception while viewing oil-based paintings. The results are as shown in table 5.4.

Table 5.3- Rotated Component Matrix of Factor analysis (oil-based paintings)

Factors	1(37.472%)	2(13.954%)	3(8.902%)	4(7.528%)
high contrast	-.077	.771	.171	-.179
warm	-.022	.905	-.117	.185
bright	-.050	.292	.761	-.312
clear	.331	.044	.130	-.660
colourful	-.041	.055	.070	-.779
natural	.419	.048	-.455	-.195
high quality	.101	-.159	-.257	-.670
active	.457	-.008	-.523	-.114
relaxed	.863	-.109	.279	-.093
soft	.744	-.013	-.096	-.029
artistic	.348	.268	-.605	-.137
lively	-.122	-.040	-.635	-.503
comfortable	.578	-.031	-.169	-.108
pleasant	.831	.000	-.050	.127

Table 5.4- t-test results for effect of spotlights on viewers' perception (oil-based paintings)

Factors	F-value	p-value
High contrast*	2.112	.001
Warm*	.444	.000
Natural	1.867	.249
Active	.008	.194
Relaxed	8.952	.101
Soft	4.129	.136
Comfortable*	.671	.010
Pleasant*	9.111	.027

*indicates that the factor is statistically significant ($p<0.05$)

Table 5.4 shows that type of spotlight has a significant impact on four factors such as high contrast, warm, comfortable and pleasant. So, from the results, it can be said that warmth feeling of viewers while viewing oil-based painting significantly changes due to the type of spotlight. In sequence, pleasant and comfort of viewing also significantly depends on the type of spotlight. Therefore, it can be concluded that for viewing oil-based paintings also, perception of viewers changes due to different types of spotlight as hypothesized in H1.

5.2.4 Preferred type of spotlight by participants for oil-based paintings:

The participants have found oil-based paintings under Halogen appearing to be 'high contrast' (OP_H= 4.67±1.061) than oil-based paintings under LED (OP_{LED}=3.60±1.221). Similarly, the painting under Halogen has appeared to be more 'warm' (OP_H=4.60±1.003) than under LED (OP_{LED}=3.03±0.928). The participants have found more 'comfortable' while viewing oil-based paintings under LED (OP_{LED}=4.73±0.828) than under Halogen (OP_H=4.07±1.081). Similarly, they have found it more 'pleasant' for viewing paintings under LED

(OP_{LED}=4.50±0.861) than under Halogen (OP_H=3.80±1.448). Hence, it is depicted that oil-based paintings under LED have low contrast, less warm, more comfortable and pleasant appearance to the viewers than under Halogen.

To verify the conclusion derived from qualitative study on viewers' perception for oil-based paintings, the data of gaze duration was statistically analyzed. Fig. 5.4 shows the plot of gaze data for oil-based paintings. From the figure, it is evident that mean value of gaze duration for oil-based painting under LED (M_{LED}=0.57, SD=0.061) is more than the mean value of gaze duration for oil-based painting under Halogen ($M_{Halogen}$=0.44, SD=0.061). So, viewers have paid more attention to the oil-based painting exhibited under LED than to the painting exhibited under Halogen.

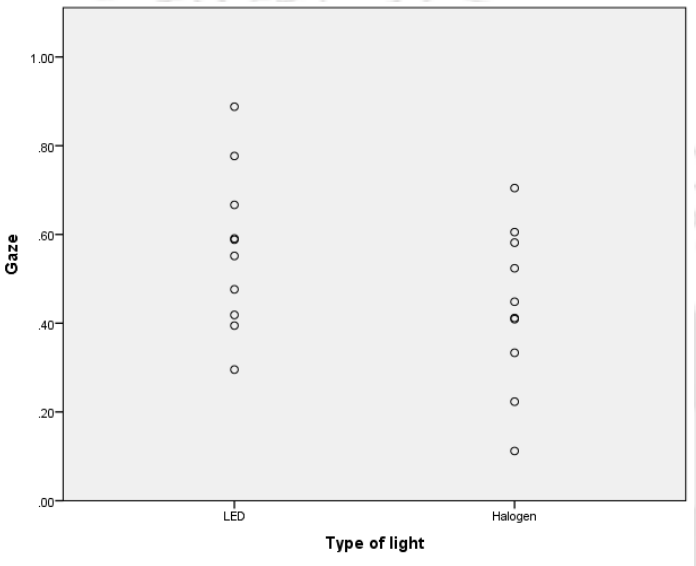

Fig.5.4. Plot of gaze data for oil-based paintings

The experimental result also indicates that for both the medium of paintings, viewers perceive identical paintings differently due to the effect of different types of spotlight. Hence, H1 is tested and verified.

5.2.5 **Effect of medium of paintings on viewers' perception:**

Based on both the experimental results associated with water-based and oil-based paintings it can be said that the effect of type of spotlight on viewers' perception while viewing paintings is similar irrespective of medium of paintings. To verify this statement t-test has been done on common significant factors derived from the previous results (shown in table 5.2 and table5. 4). The result of this test is as shown in table 5.5.

Table 5.5- t-test results for different medium of paintings

Factors	F-value	p-value
High contrast	.513	.125
Warm	5.831	.282
Comfortable	4.314	.514
Pleasant	.248	.227

Table 5.5 clearly shows that none of the factors is significantly changing ($p>.05$) with the variation of the medium of paintings. Therefore, it can be concluded that irrespective of the medium of paintings perception of viewers while viewing paintings changes due to the effect of types of spotlights.

5.3 **Discussion:**

The experimental results to verify H1 is suggesting that perception of viewers depends on types of spotlight under which paintings are being exhibited having CCT and Illuminance at a constant level. Findings from factor analysis reveals that two principal components such as 'pleasantness' and 'warmth' are driving the visual perception when viewing paintings (Fig. 5.5). Therefore, as pinpointed by the earlier researcher [47] it can be said that viewers' perception of the pleasantness depends not only on CCT and on illuminance but the type of light is also important. Also, in contradiction with an earlier study [54], it can be stated that pleasantness perception of viewers depend on types of spotlight having the same CCT.

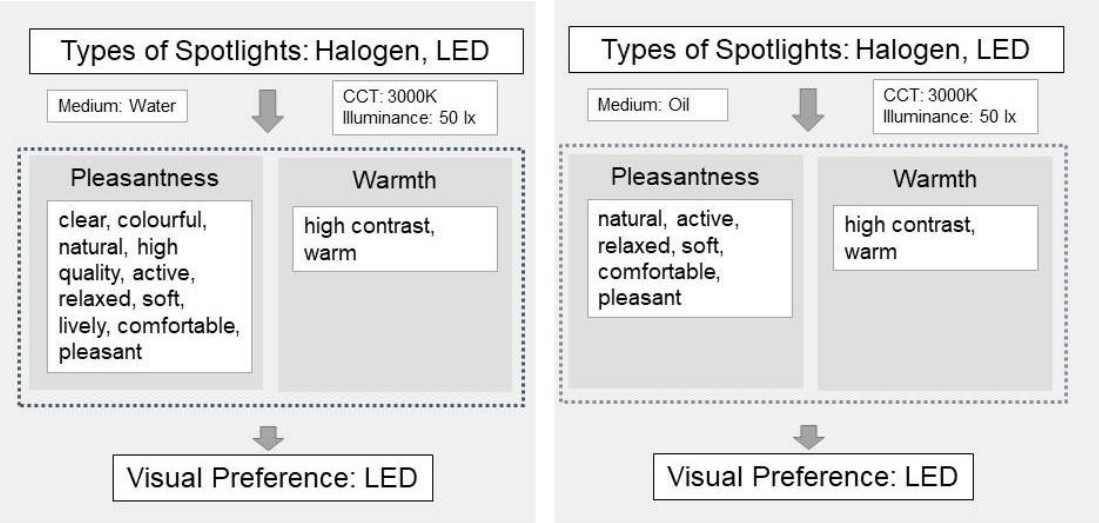

Fig. 5.5. Effect of types of spotlights on visual perception

The experimental result shows that none of the factors significantly depends on the mediums of paintings. So, type of spotlight effects perception of viewers is valid irrespective of the mediums of paintings considered in this present study (water and oil). In succession, it has been observed from gaze duration of viewers that, participants have given more attention to paintings exhibited under LED than Halogen for both mediums of

paintings. Therefore, it can be stated that, findings of this experimental study are applicable to any water and oil medium paintings.

Mean value of ratings given by viewers have revealed that for both the medium of paintings, in comparison to Halogen, LED light has appeared to be less contrast, cooler, more comfortable and pleasant to the viewers as desired by the painters. So, not only from the point of view of energy efficiency and preservation of art [23] but also from viewers' preference, the art galleries of India need to consider LED as a prime source for lighting design. In succession which colour temperature of LED is preferred by the viewers has been carried out in the next experimental study as described in the next chapter.

Chapter- 6
Testing of Hypothesis: H2

This chapter reports the result and the findings from the experiment that was conducted to test and verify H2. The chapter illustrates the effect of different CCTs on viewers' perception while viewing paintings. The qualitative and quantitative results are compared as described in the previous chapter. Then, the chapter concludes by discussing the visual preference of CCT by the viewers.

Interviews with the painters, as described in chapter 4 have revealed that most of the painters are not satisfied with the present colour temperature of light that is in use in galleries. The colour appearance of paintings is changing due to CCT of light and viewers cannot enjoy the aesthetic beauty of the original one. Also, from the literature review (chapter 2) it has been observed that there is a need to verify the effect of the only CCT on viewers' perception. Hence, to verify H2, an experimental study has been designed to examine specifically the effect of CCT on the perception of viewers while viewing paintings, keeping other light parameters (type of light and Illuminance) constant.

6.1 Methodology:

In the simulated exhibition space in the laboratory of Department of Design, IIT Guwahati, paintings were exhibited under three different CCTs keeping all other lighting parameters constant. Based on the conclusion of the previous experiment, LED has been chosen as a light source for this experiment. The position of paintings and light sources are illustrated in fig.6.1.

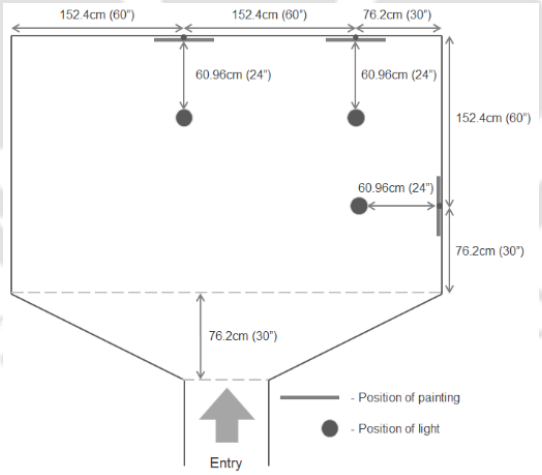

Fig. 6.1. Top view of exhibition space (not in scale)

In the previous experiment (chapter 5), it was observed that viewers' attention was frequently shifting to the white background wall. As the peripheral white surfaces attract the eye of exhibition viewers [11], therefore, it was intended to avoid such influence in this present study. Hence, a black background was created so that participants can concentrate on the paintings without any distraction. Also, the black background helps to cancel out the influence of light reflections.

6.1.1 Experimental design:

6.1.1.1 Lighting environment set up:

To verify the effect of CCT on perception of the viewers a warm white (WW) LED (CCT=2700K), a cool white (CW) LED (CCT=3500K) and an artificial Daylight (AD) LED (CCT=6500K) LED has been selected as illuminants. From the survey in galleries of India, it has been seen that there is no certain limit of the illumination level. However, from literature review, it has been found that conventional standards specify illuminance between 50 and 200 lux [91] that have been enshrined mostly based on surveys of practice across a set of major museums [92]. So, for this experimental purpose, the illuminance has been set at 100 lux which is in between this specified range. The measurement of Illuminance has been done at the center of the paintings.

6.1.1.2 Types of paintings:

Similar to the previous experiment, paintings form two different medium i.e. water and oil have been selected for stimuli. Three similar water-based paintings (11”×14”) and three similar oil-based paintings (12”×18”) drawn by professional painters have been chosen as stimuli. One sample of each type of painting is as shown in fig. 6.2, where, fig. 6.2(A) shows the sample of water-based paintings and fig. 6.2(B) shows the sample of oil-based paintings.

(A) (B)

Fig.6.2. Samples of exhibited paintings

From the experience of the previous experiment, it has been noticed that as the questionnaire is based on the appearance of paintings due to light effect, so, some participants were getting confused with the light effect of paintings itself has while responding. Hence, flat colour paintings having no light and shadow effect have been chosen for this experiment. The style of paintings was ‘Bangla Patachitra’ which is a folk art style in India and easily interpretable by the Indian viewers.

The experiment has been carried out following the study approach and procedure described in chapter 6.

6.2 Results:

6.2.1 Effect of CCT on viewers’ perception for water-based paintings:

To understand the effect of CCT on water-based paintings 14 factors have been clustered under principal factors. Table 6.1 shows the result of factor loadings with total variance explained in parenthesis for water-based paintings. From the result, it can be seen that all the factors can be explained through three main factors. Factor

1 can be named as ‘pleasantness’ which represents the atmospheric perception of lighting to the viewers while viewing paintings. It includes factors such as relaxed, comfortable, pleasant, positive impact, soft, natural and high quality. Factor 2 can be named as ‘contrast’ that defines light effect on the colour of the paintings. It includes factors like high contrast, bright, colourful and clear. Factor 3 can be named as ‘warmth’ that provides information about the appearance of paintings to the viewers under certain lighting condition. It includes factors like warm, artistic and lively. Based on PCA result, ANOVA has been done to understand the effect of different CCTs on viewers’ perception. The result is summarized in table 6.2.

Table 6.1- Rotated Component Matrix of Factor analysis (water-based paintings)

Factors	Component		
	1(35.938%)	2(23.799%)	3(13.410%)
relaxed	.865	.025	-.048
comfortable	.828	.337	.164
pleasant	.794	.441	.083
positive impact	.793	.324	.134
soft	.787	-.004	-.253
natural	.778	.116	.347
high quality	.571	.567	.263
high contrast	-.080	.835	.198
bright	.088	.772	.070
colourful	.309	.732	.150
clear	.371	.710	-.265
warm	-.126	.097	.881
artistic	.526	.057	.592
lively	.500	.487	.553

Table 6.2- ANOVA result for effect of CCTs on viewers’ perception (water-based paintings)

Dependent Variable	F- value	p-value
High contrast*	5.116	.008
Warm*	60.532	.000
Bright	2.770	.068
Clear*	4.717	.011
Colourful	1.277	.284
Natural*	5.128	.008
High quality*	9.661	.000
Positive impact*	7.217	.001
Relaxed	3.021	.054
Soft*	4.644	.012
Artistic*	6.152	.003
Lively*	11.606	.000
Comfortable*	5.245	.007
Pleasant*	5.213	.007

*indicates that the factor is statistically significant ($p<0.05$)

The ANOVA result (Table 6.2) shows that except three factors CCT has a statistically significant impact on all the factors. So, combining the results of factor analysis and ANOVA it can be said that CCT has a significant effect on the pleasantness of atmosphere, colour contrast of paintings and warmth feeling of viewers while viewing water-based paintings. Therefore, as hypothesized in H2, perception of viewers while viewing water-based paintings significantly changes due to different CCTs.

6.2.2 Preferred CCT by participants for water-based painting:

By comparing, the mean value of participants' ratings (Table 6.3), it can be observed that participants have found out 'pleasant' atmosphere for viewing paintings under CW LED than under AD LED. Again, for colour contrast of paintings participants have found out CW LED having moderately contrast effect with the colour of paintings whereas, WW LED having extreme high contrast and AD LED having extreme low contrast. However, participants have rated the appearance of painting under AD LED as more clear compared to the other two. In case of 'warmth' feeling participants have rated CW LED in between extreme warm and extreme cool whereas, WW LED having extreme warmth feeling and AD LED having extreme cool feeling. Therefore, based on the discussion with the painters, it can be said that CW LED having moderately high contrast and warm feelings help to create a pleasurable display for water-based paintings.

Table 6.3- Mean value of participants' ratings for water-based paintings

Factors	Mean±SD		
	WW LED (CCT=2700K)	CW LED (CCT=3500K)	AD LED (CCT=6500K)
High contrast	4.27±1.081	3.47±1.252	3.33±1.322
Warm	4.97±0.964	4.40±0.968	2.33±0.994
Clear	3.60±1.429	4.40±1.248	4.57±1.223
Natural	3.27±1.437	4.33±1.269	3.50±1.358
High quality	3.30±1.264	4.47±0.973	3.40±1.163
Positive impact	3.17±1.416	4.27±0.980	3.30±1.236
Soft	3.13±1.167	4.07±1.311	3.93±1.363
Artistic	3.33±1.348	4.47±1.137	4.17±1.392
Lively	3.73±1.437	4.60±1.133	3.07±1.112
Comfortable	3.60±1.354	4.67±1.155	3.87±1.456
Pleasant	3.53±1.224	4.53±1.196	3.97±1.189

To support and verify the result derived from this qualitative study, the gaze duration of viewers has been analyzed statistically. Fig.6.3 shows the plot of gaze data for water-based paintings. In the graph, X-axis represents different lamp CCTs and Y-axis represents the individual value of gaze data converted in fractional form. From fig.6.3 it is evident that mean value of gaze duration for water-based painting under CW LED (CW_{LED}=0.43, SD=0.069) is more than the mean value of gaze duration for water-based painting under WW LED (WW_{LED} =0.23, SD=0.069) and AD LED (AD_{LED}=0.33, SD=0.069). So, viewers have given more attention to

water-based painting exhibited under CW LED than the painting exhibited under WW LED and AD LED. It depicts that though the paintings were identical but viewers have perceived it differently due to the effect of different CCTs. Therefore, in accordance with the result derived from the qualitative study, this result also revealing that the perception of viewers while viewing water-based paintings changes due to different CCTs as hypothesized by H2.

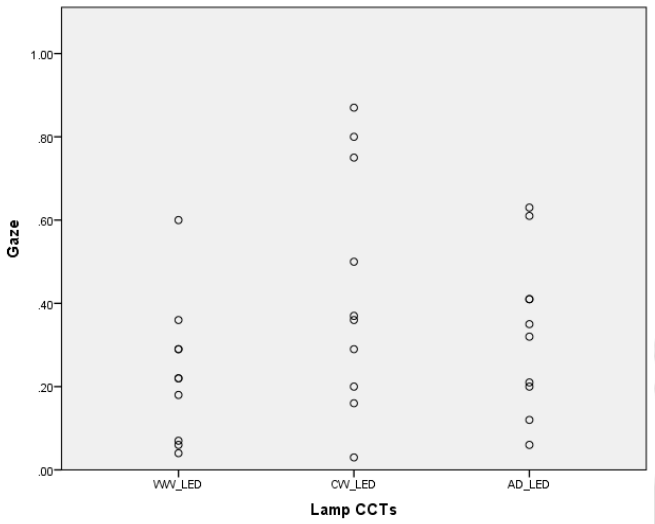

Fig.6.3. Plot of gaze data for water-based paintings

6.2.3 **Effect of CCT on viewers' perception for oil-based paintings:**

To understand the effect of CCTs on oil-based paintings similar statistical analysis method has been followed. Table 6.4 shows the result of factor loadings with total variance explained in parentheses for oil-based paintings. It can be seen from the table that among three principal factors, factor 1 explains 33.745% of variances, factor 2 explains 21.384% of variances and factor 3 explains 12.037% of variances. So, none of the factors is ignorable. Again, factor 1, 2 and 3 can be named as 'pleasantness', 'contrast' and 'warmth' respectively. In this case, pleasantness consists of factors such as positive impact, comfortable, soft, natural, pleasant, high quality and relaxed. Contrast includes factors like bright, high contrast, colourful and clear. Warmth is defined by the factors warm and artistic. ANOVA has been done on extracted factors from PCA to verify the impact of CCTs on viewers' perception while viewing oil-based paintings. The results are as shown in Table 6.5.

Table 6.4- Rotated Component Matrix of Factor analysis (oil-based paintings)

Factors	Component		
	1(33.745%)	2(21.384%)	3(12.037%)
positive impact	.821	.264	.062
comfortable	.810	.223	.176
soft	.798	.307	.009
natural	.790	.041	.151
pleasant	.751	.084	-.207
high quality	.683	.196	.156
relaxed	.673	-.024	.144
bright	.074	.829	.019
high contrast	-.015	.802	.114
colourful	.282	.791	.274
clear	.303	.712	-.038
lively	.489	.493	.438
warm	-.095	.158	.878
artistic	.473	.044	.698

Table 6.5- ANOVA result for effect of CCTs on viewers' perception (oil-based paintings)

Dependent Variable	F-value	p-value
High contrast	.376	.688
Warm*	38.739	.000
Bright	1.037	.359
Clear	1.942	.150
Colourful	1.247	.292
Natural*	6.529	.002
High quality*	15.071	.000
Positive impact*	8.887	.000
Relaxed	2.341	.102
Soft*	9.679	.000
Artistic*	6.245	.003
Lively*	3.482	.035
Comfortable*	9.056	.000
Pleasant*	9.830	.000

*indicates that the factor is statistically significant ($p<0.05$)

Table 6.5 shows that CCT has a significant impact on nine factors such as warm, natural, high quality, positive impact, soft, artistic, lively, comfortable and pleasant. So, from the results, it can be said that pleasantness of viewers while viewing oil-based painting significantly changes due to different CCT. In sequence, the warmth feeling of viewers also significantly depends on lamp CCT. However, in the case of contrast, it can be seen that CCT is not statistically significant for viewing oil-based paintings. Therefore, from the angle of pleasantness and warmth feeling while viewing oil paintings it can be concluded that, the appearance of paintings changes due to different CCTs as hypothesized in H2.

6.2.4 **Preferred CCT by participants for oil-based paintings:**

By comparing the mean value rated by participants (Table 6.6) it can be observed that participants have found out 'pleasant' atmosphere for viewing paintings more under CW LED (CCT=3500K) than under AD LED (CCT=6500K) and WW LED(CCT=2700K). Again, for warmth feeling participants have rated CW LED in between extreme warm and extreme cool whereas, WW LED having extreme warmth feeling and AD LED having extreme cool feeling. Therefore, based on the discussion with the painters, it can be said that CW LED having moderately high contrast and little warm feelings help to create a pleasurable display for oil-based paintings as well as for water-based paintings.

Table 6.6- Mean value of participants' ratings for oil-based paintings

Factors	Mean±SD		
	WW LED (CCT=2700K)	CW LED (CCT=3500K)	AD LED (CCT=6500K)
Warm	5.17±0.791	4.43±0.971	2.87±1.279
Natural	3.37±1.299	4.47±1.074	3.47±1.502
High quality	3.17±1.177	4.60±0.894	3.57±1.040
Positive impact	3.47±1.306	4.80±1.064	4.00±1.313
Soft	3.40±1.248	4.67±1.061	4.10±1.029
Artistic	3.57±1.524	4.67±1.028	4.47±1.252
Lively	3.77±1.331	4.57±0.898	4.13±1.252
Comfortable	3.17±1.440	4.37±0.850	3.33±1.184
Pleasant	3.03±1.098	4.23±1.104	4.07±1.202

To support and verify the result derived from this qualitative study, the gaze duration of viewers has been analyzed statistically. Fig.6.4 shows the plot of gaze data for oil-based paintings. In the graph, X-axis represents different lamp CCTs and Y-axis represents the individual value of gaze data converted in fractional form.

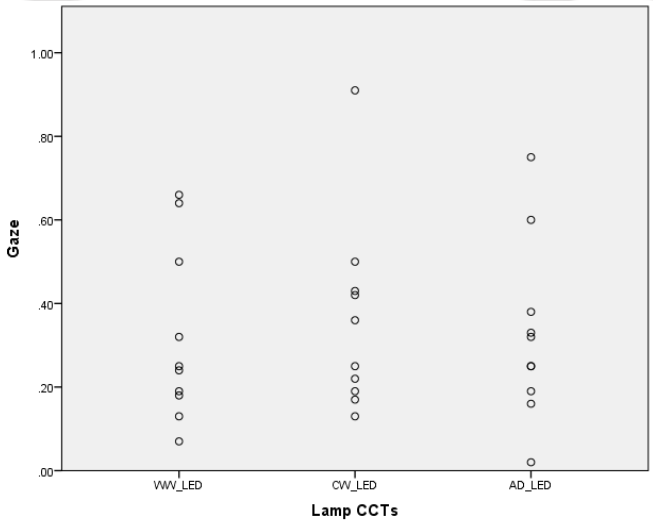

Fig.6.4. Plot of gaze data for oil-based paintings

From fig.6.4 it is obvious that mean value of gaze duration for oil-based painting under CW LED (CW_{LED}=0.36, SD=0.069) is more than the mean value of gaze duration for oil-based painting under WW LED (WW_{LED} =0.32, SD=0.069) and AD LED (AD_{LED}=0.33, SD=0.069). So, viewers have given more attention to oil painting exhibited under CW LED than the painting exhibited under WW LED and AD LED. It depicts that though the paintings were identical but viewers have perceived it differently due to the effect of lamp CCTs. Therefore, in accordance with the result derived from the qualitative study, this result also reveals that the perception of viewers while viewing oil-based paintings changes due to different CCTs as hypothesized by H2.

6.2.5 **Effect of medium of paintings on viewers' perception:**

Based on both the experimental results associated with water-based and oil-based paintings it can be said that the effect of CCT on viewers' perception while viewing paintings is similar irrespective of the medium of paintings. To verify this statement t-test has been done on common significant factors derived from the previous results (shown in table 6.2 and table 6.5). The result of this test is as shown in Table 6.7.

Table 6.7- t-test results for different medium of paintings

Dependent Variable	F-value	p-value
Warm	0.697	0.405
Natural	0.389	0.534
High quality	0.268	0.606
Positive impact	0.127	0.722
Soft	2.696	0.102
Artistic	0.167	0.684
Lively	2.269	0.134
Comfortable	0.160	0.690
Pleasant	0.200	0.655

Table 6.7Table clearly shows that none of the factors is significantly changing ($p>.05$) with the variation of the medium of paintings. Therefore, it can be concluded that irrespective of the medium of paintings perception of viewers while viewing paintings changes due to the effect of CCTs.

6.3 **Discussion:**

The experimental results to verify H2 is suggesting that the perception of viewers depends on lamp CCT keeping other light parameters constant. Also, the result of this experimental study is revealing that the appearance of paintings is effected by the CCTs is valid irrespective of the medium of paintings considered in this present study. Therefore, it can be stated that H2 is applicable for any water and oil medium paintings. In succession, this experimental result depicts that CCT alone has a significant effect on the perception of pleasantness, which contradicts with previous studies [52] [53] [55]. Possibly, this contradiction has risen as because earlier studies are applicable for general room illumination, not for looking at any artwork. In succession, an earlier study on lighting condition for viewing painting concluded that viewer's preference is negatively correlated

with CCT [60] can be partially agreed as because from this experimental result it has been seen that viewers have preferred CW LED over WW LED. Perhaps, similarity among the paintings has helped viewers to understand and differentiate the effect of CCT more precisely. Moreover, the difference in geographical factor leads to variation in colour preference [93] that may be applicable for preference of colour temperature of lamp also.

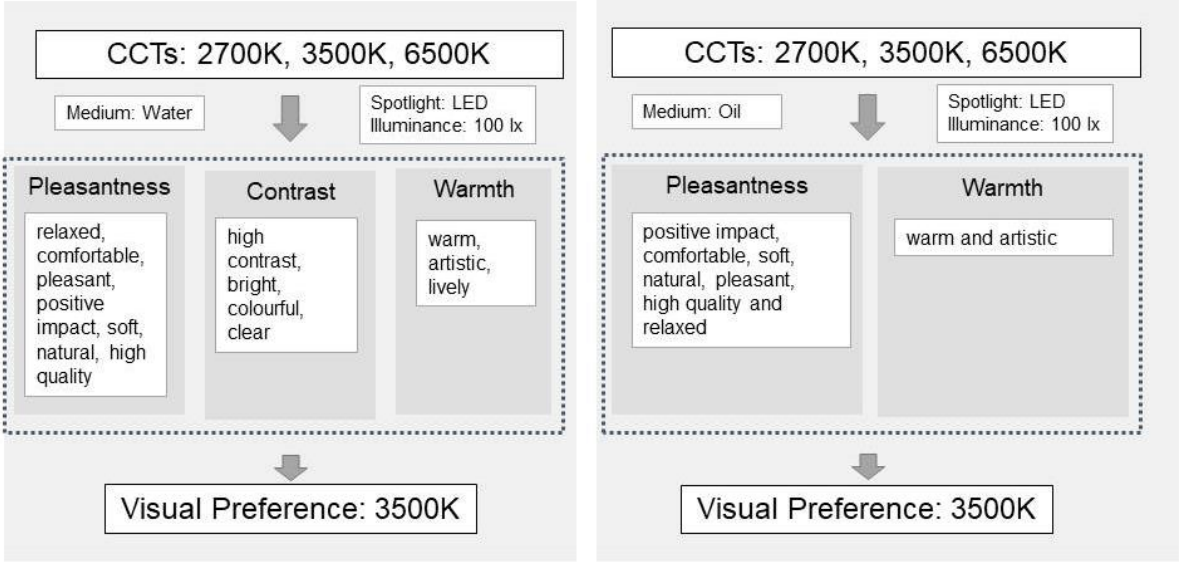

Fig. 6.5. Effect of CCTs on visual perception

Experimental result of this present study as summarized in fig.6.5 reveals that three principal factors, namely, pleasantness, contrast and warmth determining the effect of CCT on the appearance of water-based paintings and two principal factors, namely, pleasantness and warmth determining the effect of CCT on the appearance of oil-based paintings. By comparing the mean values of viewers' preference, it has been observed that for both medium of paintings, in comparison to WW LED and AD LED, CW LED creates more pleasant appearance of paintings. Also, from the data of viewers' gaze duration on paintings, it has been seen that participants have given more attention to paintings exhibited under CW LED than other two light sources. Therefore, in tune with earlier researchers [91], it can be concluded that CW LED with 3500K colour temperature has moderately warm effects on the appearance of paintings that lies in between cool and warm.

The results of this experimental study are suggesting that the art galleries of India need to consider CW LED as a prime source for lighting design to enrich viewers' satisfaction. In succession which illumination level of CW LED is preferred by the viewers, need to be understood. In the next chapter, an experiment has been carried out to verify the effect of illumination levels on perception of viewers.

Chapter- 7
Testing of Hypothesis: H3

This chapter describes the experimental results and findings that have been carried out to test and verify H3. Lighting survey data in selected galleries of India (chapter 4) has revealed that Illumination level has no particular level or limit within which the paintings are displayed. In some galleries, overexposed lighting design technique with Halogen as spotlight has been used which is a kind of merchandise lighting techniques [5] arising ethical question for a painting exhibition. Also, the literature review (chapter 2) has revealed that there is a need to verify the effect of Illuminance on viewers' perception. Therefore, to verify H3, a study has been designed to examine specifically the effect of Illumination level on viewers' perception when viewing paintings keeping CCT and Illuminance constant.

7.1 Methodology:

In same experimental space as described in chapter 6 (fig. 6.1), three similar paintings were exhibited under LEDs with different illumination levels keeping CCT at constant. Qualitative as well as quantitative approaches have been taken to understand the effect of different illumination levels on viewers' perception while viewing paintings.

7.1.1 Experimental design:

7.1.1.1 Lighting environment set up:

It has been found from the previous experimental result (testing of H2), viewers have preferred to view paintings under CW LED (CCT=3500K). Therefore, to verify the effect of Illuminance on the perception of the viewers, CW LED has been selected as illuminants. From the survey in galleries of India, it has been seen that there is no certain limit of illumination level. However, from literature review, it has been found that conventional standards specify Illuminance between 50 and 150 lux [90] that has been enshrined mostly based on surveys of practice across a set of major museums [92]. So, for this experimental purpose the Illuminance has been set at three levels, i.e. 50lux (I_{50}), 100 lux (I_{100}) and 150 lux (I_{150}) which are in between this specified range. The measurements of vertical Illuminance has been taken on the center point of the plane of the exhibited paintings with standard Luxmeter (METRAVI 1332) and the light level on the plane of paintings were controlled by varying the voltages through Variac (1-phase/ 0 to 270V AC / 1A).

7.1.1.2 Types of paintings:

Three identical 'Bangla Patachitra' style water-based paintings (11"×14") and oil-based paintings (12"×18") drawn by professional painters have been chosen as stimuli. One sample of each type of painting is as shown in fig. 7, where, fig. 7.1(A) shows the sample of water-based paintings and fig. 7.1(B) shows the sample of oil-based paintings.

(A) water-based painting

(B) Oil-based painting

Fig.7.1. Samples of exhibited paintings

The experiment has been carried out following the study approach and procedure described in chapter 6.

7.2 Results:

7.2.1 Effect of illumination level on viewers' perception for water-based paintings:

To understand the effect of different illumination levels on viewers' perception when viewing water-based paintings, 14 factors have been clustered under two principal factors as shown in table 7.1. Factor 1 can be named as 'pleasantness' which represents the atmospheric perception of lighting to the viewers while viewing paintings. It includes factors such as bright, high contrast, colourful, clear, lively, high quality, positive impact, pleasant, comfortable and warm. Factor 2 can be named as 'naturalness' that provides information about the effect of illumination level on the colour of the paintings. It includes factors such as relaxed, soft, natural and artistic. Based on PCA result, ANOVA has been done to understand the effect of different illumination levels on viewers' perception when viewing water-based paintings. The result is summarized in table 7.2.

Table 7.1- Rotated Component Matrix of Factor analysis (water-based paintings)

	Components	
Factors	1(46.465%)	2(22.715%)
bright	.904	-.142
high contrast	.890	-.146
colourful	.886	.148
clear	.866	.004
lively	.864	.211
high quality	.834	.244
positive impact	.727	.387
pleasant	.719	.396
comfortable	.624	.400
warm	.615	-.300
relaxed	.045	.857
soft	-.192	.789
natural	.185	.781
artistic	.173	.700

Table 7.2- ANOVA result for effect of illumination levels on viewers' perception (water-based paintings)

Dependent variables	F-value	p-value
Bright*	117.831	.000
High contrast*	71.340	.000
Colourful*	76.924	.000
Clear*	57.903	.000
Lively*	59.325	.000
High quality*	51.459	.000
positive impact*	20.684	.000
Pleasant*	24.007	.000
Comfortable*	13.219	.000
Warm*	16.245	.000
Relaxed	.020	.980
Soft	2.384	.098
Natural	.566	.570
Artistic	.380	.685

*indicates that the factor is statistically significant ($p<0.05$)

The ANOVA result (table 7.2) shows that except four factors Illuminance has a statistically significant impact on all the factors. So, combining the results of factor analysis and ANOVA it can be said that Illuminance has a significant effect on the pleasantness of viewers while viewing water-based paintings. However, the experimental result depicts that the naturalness of paintings does not depend significantly on illumination level. Therefore, it can be said that perception of viewers in terms of pleasantness significantly changes due to different illumination levels on water-based paintings.

7.2.2 **Preferred Illumination level by participants for water-based paintings:**

To understand the participants' preferable illumination level, mean values of ratings for all significant factors have been compared. From table 7.3 it can be observed that participants have found out 'pleasant' atmosphere for viewing paintings under 100 lux illumination level (I_{100}) than under 50 lux (I_{50}) and 150 lux (I_{150}) illumination level. Therefore, it can be said that 100 lux illumination level helps to create a pleasurable visual display for water-based paintings.

Table 7.3- Mean value of participants' ratings for water-based paintings

Factors	Mean±SD		
	Illuminance=50lux (I_{50})	Illuminance=100lux (I_{100})	Illuminance=150lux (I_{150})
Bright	2.07±0.740	5.33±0.884	4.17±0.874
High contrast	2.23±1.006	5.00±0.788	3.93±0.907
Colourful	2.27±.740	4.97±0.890	4.03±0.928
Clear	3.03±1.066	5.33±0.758	5.00±0.830
Lively	2.47±0.973	5.00±0.830	4.13±0.937
High quality	2.53±1.008	5.00±0.830	4.23±1.040
Positive impact	2.80±1.095	4.60±1.133	4.07±1.112
Pleasant	2.97±1.033	4.77±1.135	4.43±1.04
Comfortable	3.20±1.157	4.63±1.066	4.37±1.217
Warm	3.03±1.098	4.63±0.964	4.10±1.242

To support and verify the result derived from this qualitative study, the gaze duration of viewers has been analyzed as mentioned in equation 1. Fig.7.2 shows the plot of gaze data for water-based paintings. In the graph, X-axis represents different Illumination levels and Y-axis represents the individual value of gaze data converted in fractional form.

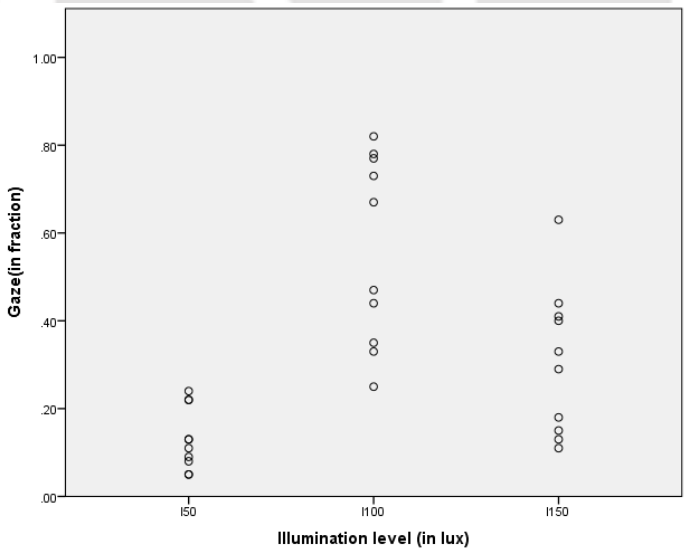

Fig.7.2. Plot of gaze data for water-based paintings

From fig.7.2 it can be observed that mean value of gaze duration for water-based painting under I_{100} (I_{100}=0.56, SD=0.215) is more than mean value of gaze duration for water-based painting under I_{50} (I_{50} =0.13, SD=0.071) and I_{150} (I_{150}=0.31,

SD=0.168). So, viewers have given more attention to water-based painting exhibited under I_{100} than the painting exhibited under I_{50} and I_{150}. It depicts that though the paintings were identical but viewers have perceived it differently due to the effect of different illumination levels. Also, in accordance with the result derived from the qualitative study, this result also reveals that viewers have preferred viewing water-based painting exhibited under 100 lux illumination level than the paintings exhibited under 50 lux and 150lux levels.

7.2.3 Effect of illumination level on viewers' perception for oil-based paintings:

To understand the effect of different illumination levels on oil-based paintings similar statistical analysis method has been followed. Table 7.4 shows the result of factor loadings with total variance explained in parentheses for oil-based paintings. From the result, it can be seen that all the factors can be explained through two main factors. Factor 1 can be named as 'brightness' that defines the effect of light level on the appearance of the paintings. It includes factors like bright, colourful, high contrast, clear, warm, high quality, lively and positive impact. Factor 2 can be named as 'pleasantness' which represents the atmospheric perception of lighting to the viewers while viewing paintings. It includes factors such as relaxed, natural, comfortable, pleasant, artistic and soft. Based on PCA result, ANOVA has been done to understand the effect of different illumination levels on perception of viewers.

Table 7.4- Rotated Component Matrix of Factor analysis (oil-based paintings)

	Component	
Factors	1(45.421%)	2(26.432%)
bright	.914	-.031
colourful	.912	.054
high contrast	.903	-.096
clear	.868	.170
warm	.823	-.164
high quality	.787	.259
lively	.767	.295
positive impact	.661	.545
relaxed	-.246	.800
natural	.005	.795
comfortable	.404	.776
pleasant	.493	.698
artistic	.083	.663
soft	-.572	.617

Table 7.5- ANOVA result for effect of illumination levels on viewers' perception (oil-based paintings)

Dependent variables	F-value	p-value
Bright*	152.463	.000
Colourful*	89.753	.000
High contrast*	68.250	.000
Clear*	44.616	.000
Warm*	36.585	.000
High quality*	20.796	.000
Lively*	26.201	.000
Positive impact*	17.606	.000
Relaxed*	5.057	.008
Natural	1.811	.170
Comfortable*	8.275	.001
Pleasant*	11.048	.000
Artistic	1.370	.260
Soft*	21.900	.000

*indicates that the factor is statistically significant ($p<0.05$)

Table 7.5 shows that except two factors Illumination level have a significant impact on all other factors. So, from the results, it can be said that pleasantness of viewers while viewing oil-based painting significantly changes due to different illumination levels. In sequence, the appearance of brightness of paintings to the viewers also significantly depends on Illumination levels. Therefore, it can be inferred that the perception of viewers when viewing oil-based paintings significantly changes due to different Illumination levels of the illuminants.

7.2.4 **Preferred Illumination level by participants for oil-based paintings:**

By comparing the mean value rated by participants (Table 7.6) it can be observed that participants have found out 'pleasant' atmosphere for viewing paintings more under I_{150} than under I_{50} and I_{100}. Therefore, it can be said that 150lux illumination level helped to create a pleasurable visual display for oil-based paintings. Hence, in contrary to preferred illumination level for water-based paintings (i.e. 100lux), participants have preferred 150lux illumination level as more comfortable for viewing in case of oil-based paintings.

Table 7.6- Mean value of participants' ratings for oil-based paintings

Factors	Mean±SD		
	Illuminance=50lux (I_{50})	Illuminance=100lux (I_{100})	Illuminance=150lux (I_{150})
Bright	1.97± 0.765	5.43±0.626	4.07±0.907
Colourful	2.50±1.009	5.40±0.675	4.63±0.890
High contrast	2.50±1.137	5.23±0.728	4.13±0.819
Clear	2.80±1.186	5.23±1.040	4.67±0.884
Warm	2.70±1.119	4.93±0.828	4.10±1.094
High quality	3.07±1.081	4.80±1.031	4.23±1.073
Lively	2.70±1.149	4.57±1.073	4.37±1.066
Positive impact	2.97±0.890	4.33±1.269	4.37±0.928
Relaxed	3.87±1.332	3.13±1.252	4.13±1.196
Comfortable	3.13±1.279	4.03±1.450	4.47±1.137
Pleasant	3.17±1.367	4.10±1.348	4.73±1.172
Soft	4.50±1.042	2.80±1.126	3.80±1.095

To support and verify the result derived from this qualitative study, the gaze duration of viewers has been analyzed following the equation 1. Fig.7.3 shows the plot of gaze data for oil-based paintings. In the graph, X-axis represents different illumination levels and Y-axis represents the individual value of gaze data converted in fractional form.

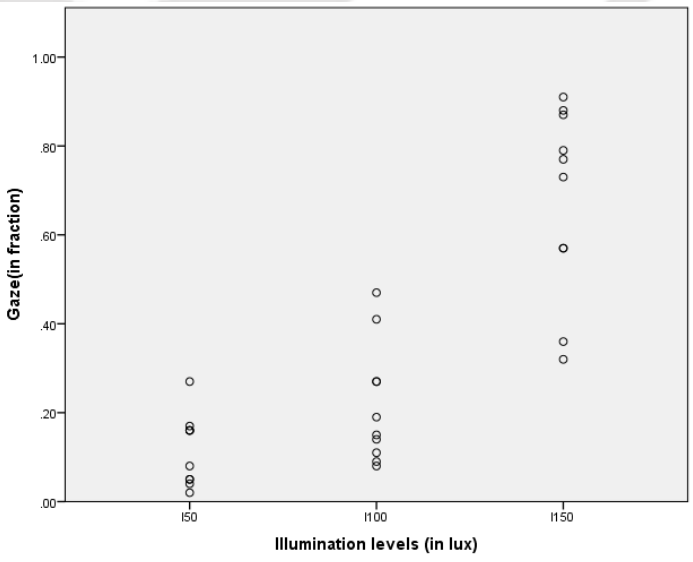

Fig.7.3. Plot of gaze data for oil-based paintings

From fig. 7.3 it can be observed that mean value of gaze duration for oil-based painting under I_{150} (I_{150}=0.68, SD=0.213) is more than the mean value of gaze duration for oil-based painting under I_{50} (I_{50} =0.12, SD=0.080) and I_{100} (I_{100}=0.22, SD=0.135). So, viewers have given more attention to oil-based painting exhibited under I_{150} than the painting exhibited under I_{50} and I_{100}. It depicts that though the paintings were identical but viewers have perceived it differently due to the effect of different illumination levels. Therefore, in accordance with the result derived from the qualitative study, this result is also revealing that viewers have preferred viewing oil-based painting exhibited under 150lux illumination level than the paintings exhibited under 50 lux and 100lux levels.

7.2.5 Effect of medium of paintings on viewers' perception:

From the contradiction between preferred illumination levels for the different medium of paintings, it can be assumed that preferred illumination level for viewing paintings changes depending on the medium of paintings. To verify this statement t-test has been done on common significant factors derived from the previous results (shown in table 7.2 and table 7.5). The result of this test is as shown in table 7.7.

Table 7.7- t-test results for different medium of paintings

Dependent variables	F-value	p-value
Bright	.272	.890
High contrast	.185	.282
Colourful	.540	.053
Clear	.612	.292
Lively	.002	.957
High quality	1.570	.580
positive impact	1.259	.727
Pleasant	.573	.787
Comfortable	.251	.348
Warm	.331	.955

Table 7.7 clearly shows that none of the factors is significantly changing (p>.05) with the variation of medium of paintings. Therefore, the assumption that the preferred illumination level for viewing paintings changes depending on the medium of paintings is not valid. However, though the medium of paintings does not have statistically significant effect on the considered factors but the variations of preferred illumination levels with the medium of paintings cannot be ignored.

7.3 Discussion:

The experimental results to verify H3 is suggesting that perception of viewers changes due to different illumination level keeping other lighting parameters (type of light & CCT) constant. Findings from experimental results (fig. 7.4) show that principal factor pleasantness is determining the effect of Illuminance on the perception of viewers for water-based paintings and two principal factors, namely, pleasantness and brightness determining the effect of Illuminance on the perception of viewers for oil-based paintings. Therefore, these findings establish that Illuminance has a significant effect on the perception of brightness or pleasantness that contradicts with the previous study [51]. In addition, both mediums of paintings, preferred illumination levels are more than recommended 50lux level [94] [31] [32]. Therefore, contradicting with earlier studies [33] [34] [35], it can be said that considering the viewers' comfort for visibility recommended light level is not enough illumination level for viewing paintings. Incidentally, it can be noted that though there is atmospheric variation (e.g. temperature, humidity) among different countries but the recommended light level is same. Possibly, in view of conservation of paintings also, this recommendation should vary depending on different atmospheric factors.

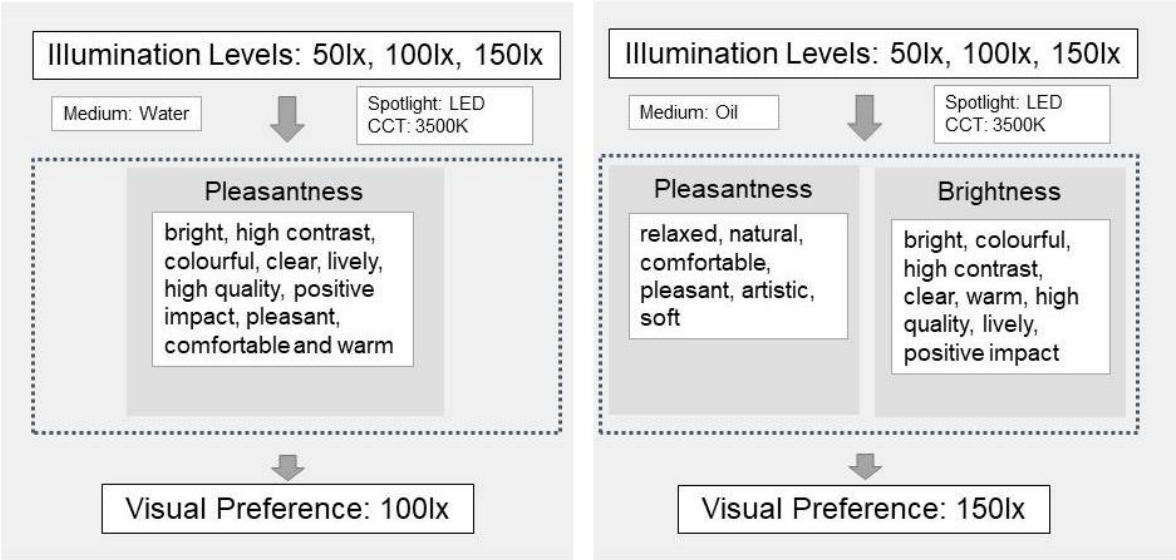

Fig. 7.4. Effect of Illumination levels on visual perception

From the data of viewers' gaze duration on water-based paintings, it has been seen that participants have given more attention to paintings exhibited under I_{100} than under I_{50} and I_{150}, whereas, in case of oil-based paintings participants have paid more attention to paintings exhibited under I_{150} than under I_{50} and I_{100}. Therefore, art galleries need to increase standard illumination level higher than 50lux. Again, an increase of illumination level will help to create pleasant visual display is not acceptable as because viewers have preferred 100lux over 150lux Illumination level in case of water-based paintings. Therefore, though according to the experimental result, the medium of paintings does not play a significant role on viewers' perception, but the dependency of preferred illumination level on the different medium of paintings cannot be ignored. An earlier study on the detrimental effects of different light sources on paintings it has been observed that LED

causes less temperature rise and change in relative humidity as compared to other conventional light sources [23]. So, the cracking of paint, i.e. the damage which is caused by continuous heating and fading of colour i.e. photochemical degradation of the surface which is caused by moisture content, is lower in the case of LED [95] than with other light sources. It has also been found that LED provides very low values of the effective radiant exposure compared to other conventional light sources [95]. At present, only the Canadian Conservation Institute [96] has appeared to implement situation-specific resolutions [97] for lighting design in art galleries which include a balance between requirements of visibility level with the conservation of art exhibits. It has been discussed through the experimental study that recommended illumination level for art galleries should be increased under a specific situation for proper visibility [97]. Such situations include artefacts with low contrast details, dark surfaces, where complex visual searches may be required within a limited time and for older viewers. In each of these cases, up to three times the basic recommended light intensity (50 lux) can be employed ideally compensating by proportional 'dark periods' as suggested by him. However, these studies maintain the recommended Lux-Hours (Illuminance× Exposure time) by CIE [94]. Thus, only the visibility level has been enhanced in specific circumstances but whether standard recommendation level can be modified with the advancement of lighting technology and sources has not been discussed. So, there is a scope to increase the existing recommended level of illuminance in case of lighting with LEDs for art galleries which will increase the brightness of the paintings by satisfying pleasantness of viewers.

The experiments to understand the individual effect of different light parameters (type of spotlight, CCT, Illuminance) on viewers' perception has been discussed since now. A further experiment has been carried out to understand viewers' preferred lighting condition with a combination of different light parameters as described in the next chapter.

Chapter- 8
Visual Preference for Effective Spotlight Design

This chapter reports the viewers' preferred lighting conditions (spotlight) in painting exhibition based on the experimental results and findings. This experiment has been designed based on previous experimental findings as described in the earlier three chapters.

The interviews (chapter 4) with the exhibition stakeholders and lighting professionals have revealed that though there is a difference in terms of lighting design process between them but both of them have preferred LED lighting for an art exhibition. Also, findings from experimental results to verify H1 (chapter 5) has revealed that viewers have preferred paintings under LED light than under conventional tungsten Halogen light. In addition, from experimental results to verify H2 and H3 (chapter 6 and chapter 7) it has been observed that light parameters such as CCT and Illuminance individually have a significant effect on the perception of the viewers. However, which combination of CCT and Illuminance will be able to create a visually pleasant atmosphere that need to be found out. Current lighting design practice for painting exhibition is often based on a canonical set of illumination functions by Kruithof [44] that are said to reveal preferred combinations of illuminance and correlated colour temperature (CCT) for interior lighting conditions [89]. A study [62] to understand viewers' preferred lighting conditions for viewing paintings has concluded that Kruithof's graph [44] recommendation for preferred CCT and Illuminance may not be suitable for LED lighting for viewing fine art objects. Therefore, an experiment has been designed to understand the preferred combination of CCT and Illuminance while viewing paintings exhibited under LED lights.

8.1 Methodology:

In simulated exhibition space as described in chapter 6 (fig. 6.1), paintings were exhibited under three different CCT with three different illumination levels of LEDs. The experiment was conducted following the methodology as discussed in chapter 3.

8.1.1 Experimental design:

8.1.1.1 Lighting environment set up:

To understand the preferred combination of CCT and Illuminance while viewing paintings exhibited under LED lights, a warm white (WW) LED (CCT=2700K), a cool white (CW) LED (CCT=3500K) and an artificial Daylight (AD) LED (CCT=6500K) LED have been selected as illuminants. As according to Kruithof's graph [44], viewers will find 'pleasing' in high CCT illumination at high Illuminance and low CCT Illumination at low Illuminance, therefore, WW LED with 50lux (I_{50}), CW LED with 100 lux (I_{100}) and AD LED with 150 lux (I_{150}) focusing on vertical plane of paintings have been set. Therefore, three sets of lighting combinations were created. They are:

L1: WW LED, I_{50}
L2: CW LED, I_{100}
L3: AD LED, I_{150}

The measurements of vertical Illuminance has been taken on center point of the plane of the exhibited paintings with standard Luxmeter (METRAVI 1332). The values of the light level on the plane of paintings were controlled by varying the voltages through Variac (1-phase/ 0 to 270V AC / 1A)

8.1.1.2 Types of paintings:

Paintings (Fig.7.1) those were used for testing H3 have been exhibited for this experiment also. Same paintings were kept as an exhibit to understand whether the preference of illumination level changes with the variation of CCTs.

The experiment has been carried out following the study approach and procedure described in chapter 3.

8.2 Results:

8.2.1 Effect of CCT and Illuminance on perception of viewers' for water-based paintings:

To understand the effect of CCT and Illuminance on viewers' perception when viewing water-based paintings, 14 factors have been clustered under principal factors. Table 8.1 shows the result of factor loadings with total variance explained in parentheses for water-based paintings. From the table it can be seen that all the factors can be clustered under three principal factors. Factor 1 can be named as 'pleasantness' which represents the atmospheric perception of lighting to the viewers while viewing paintings. It includes factors such as pleasant, comfortable, positive impact, soft, relaxed, lively, colourful, high quality and natural. Factor 2 can be named as 'brightness' that defines the effect of light level on the appearance of the paintings. It includes factors like bright, high contrast and clear. Factor 3 can be named as 'warmth' that provides information about the appearance of paintings to the viewers under certain colour temperature of light. It includes factors like warm and artistic. Based on PCA result, ANOVA has been done to understand the effect of CCT and Illuminance on viewers' perception while viewing water-based paintings.

Table 8.1- Rotated Component Matrix of Factor analysis (water-based paintings)

Factors	Component		
	1(37.953%)	2(16.520%)	3(12.083%)
pleasant	.847	.153	.116
comfortable	.846	.140	.074
positive impact	.842	.137	.145
soft	.822	-.102	.010
relaxed	.814	.130	-.033
lively	.682	.234	.347
colourful	.640	.493	.190
high quality	.519	.464	.389
natural	.510	.047	.469
bright	.171	.809	-.222
high contrast	-.190	.774	.109
clear	.372	.646	-.105
warm	-.071	-.052	.874
artistic	.468	-.189	.535

Table 8.2- ANOVA result for effect of CCT and Illuminance on viewers' perception (water-based paintings)

Dependent Variable	F-value	p-value
High contrast	2.925	.059
Warm*	30.420	.000
Bright*	10.005	.000
Clear*	3.540	.033
Colourful	1.286	.282
Natural*	7.528	.001
High quality	1.682	.192
Positive impact*	3.693	.029
Relaxed	1.425	.246
Soft*	3.546	.033
Artistic*	7.531	.001
Lively	1.343	.266
Comfortable*	6.487	.002
Pleasant*	7.169	.001

*indicates the factor is statistically significant ($p<0.05$)

The ANOVA result (Table 8.2) shows that lighting parameters (CCT and Illuminance) have a statistically significant impact on 9 of the 14 factors considered in this study. So, combining the results of factor analysis and ANOVA it can be said that CCT and Illuminance have a significant effect on the pleasantness of

atmosphere, the brightness of paintings and the warmth feeling of viewers while viewing water-based paintings.

8.2.2 Preferred CCT and Illuminance combination by participants for water-based paintings:

By comparing the mean value of participants' ratings (Table 8.3), it can be observed that participants have found out 'pleasant' atmosphere for viewing paintings under light set L2 than under L1 and L3. Again, for the brightness of paintings participants has found out L2 having a moderately bright effect on the colour of paintings whereas, L3 is having extreme bright and L1 having dimmed effect on painting. However, participants have found out L1 having more artistic effect on the appearance of painting compared to L2 and L3. In the case of 'warmth' feeling, participants have rated L2 in between extreme warm and extreme cool whereas, L1 is having extreme warmth feeling and L3 having extreme cool feeling. Therefore, it can be said that L2 i.e. CW LED with 100lux illumination level having moderate brightness and warm feelings helps to create a pleasurable display for water-based paintings.

Table 8.3- Mean value of participants' ratings for water-based paintings

Factors	Mean ± SD		
	L1: WW LED, I_{50}	L2: CW LED, I_{100}	L3: AD LED, I_{150}
Warm	4.70± 0.220	3.96±0.220	2.33±0.220
Bright	3.26±0.211	3.96±0.211	4.60±0.211
Clear	4.03±0.228	4.83±0.228	4.70±0.228
Natural	3.96±0.211	4.20±0.211	3.10±0.211
Positive impact	4.00±0.209	4.33±0.209	3.53±0.209
Soft	3.90±0.238	4.13±0.238	3.26±0.238
Artistic	4.20±0.218	4.13±0.218	3.13±0.218
Comfortable	3.43±0.246	4.66±.246	3.86±0.246
Pleasant	3.56±0.197	4.60±0.197	3.90±0.197

To support and verify the result derived from this qualitative study, the gaze duration of viewers has been analyzed statistically. Fig.8.1 shows the plot of gaze data for water-based paintings. In the graph, X-axis represents light parameters and Y-axis represents the individual value of gaze data converted in fractional form.

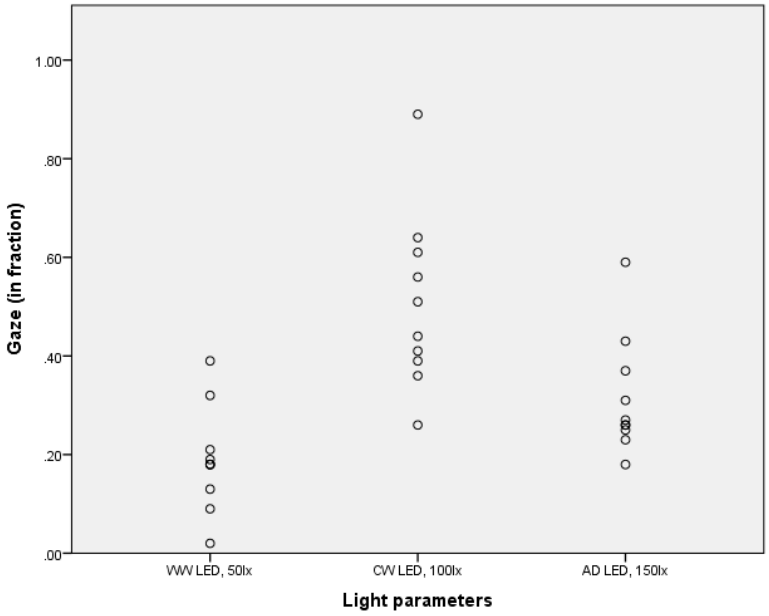

Fig.8.1. Plot of gaze data for water-based paintings

From fig.8.1 it is obvious that mean value of gaze duration for water-based painting under CW LED with 100lux level (L2=0.51, SD=0.179) is more than the mean value of gaze duration for water-based painting under WW LED with 50lux level (L1 =0.19, SD=0.105) and AD LED with 150lux level (L3=0.31, SD=0.120). So, viewers have given more attention to water-based painting exhibited under CW LED in 100 lux level than the painting exhibited under WW LED and AD LED with 50lux and 150lux level respectively. It depicts that though the paintings were identical but viewers have preferred viewing particularly under CW LED with 100 lux illumination level. Therefore, in accordance with the result derived from the qualitative study, this result also is revealing that best possible appearance of paintings to viewers while viewing water-based paintings could be achieved under CW LED having 100 lux light level on the plane of the paintings.

8.2.3 Effect of CCT and Illuminance on perception of viewers' for oil-based paintings:

To understand the effect of CCT and Illuminance on viewers' perception when viewing oil-based paintings similar statistical analysis method has been followed. Table 8.4 shows the result of factor loadings with total variance explained in parentheses for oil-based paintings. Again, factor 1, 2 and 3 can be named as 'pleasantness', 'brightness' and 'warmth' respectively. In this case, pleasantness consists of factors such as comfortable, pleasant, relaxed, positive impact, soft, lively, artistic, natural and high quality. Brightness includes factors like high contrast, bright, clear and colourful. Warmth is defined by the factors warm. ANOVA has been done on extracted factors from PCA to verify the impact of CCT and Illuminance on viewers' perception.

Table 8.4- Rotated Component Matrix of Factor analysis (oil-based paintings)

Factors	Component		
	1(44.785%)	2(19.072%)	3(10.890%)
comfortable	.921	.168	-.048
pleasant	.884	.158	.051
relaxed	.874	.082	-.015
positive impact	.854	.205	.087
soft	.835	-.093	.059
lively	.733	.439	.096
artistic	.732	.020	.474
natural	.686	.193	.471
high quality	.684	.432	.221
high contrast	-.190	.806	.124
bright	.134	.747	-.406
clear	.374	.673	-.201
colourful	.481	.665	-.026
warm	.114	-.200	.885

Table 8.5- ANOVA result for effect of CCT and Illuminance on viewers' perception (oil-based paintings)

Dependent Variable	F-value	p-value
High contrast*	4.386	.015
Warm*	40.854	.000
Bright*	25.928	.000
Clear*	7.894	.001
Colourful*	4.310	.016
Natural*	6.546	.002
High quality	1.219	.300
Positive impact*	8.445	.000
Relaxed	2.559	.083
Soft*	3.560	.033
Artistic*	13.543	.000
Lively*	4.263	.017
Comfortable*	4.791	.011
Pleasant*	7.021	.001

*indicates the factor is statistically significant ($p<0.05$)

Table 8.5 shows that except two factors CCT and Illuminance had a significant impact on all factors considered in this experiment. So, from the results, it can be said that pleasantness of viewers while viewing oil-based painting significantly changes due to different CCT and Illuminance. In sequence, the brightness of painting and warmth feeling of viewers also significantly depends on CCT and Illuminance. Therefore, it can be concluded that perception of pleasantness,

brightness and warmth changes due to different CCTs and Illuminances while viewing oil-based paintings.

8.2.4 **Preferred CCT and Illuminance by participants for oil-based paintings:**

By comparing the mean value rated by participants (Table 8.6) it can be observed that participants have found out 'pleasant' atmosphere for viewing paintings more under L2 (CW LED, I_{100}) than under L3 (AD LED, I_{150}) and L1(WW LED, I_{50}). Again for the bright appearance of paintings participants have rated L2 having a moderately bright effect on paintings whereas L3 having extreme brightness and L1 having dimmed effect on paintings. In case of warmth feeling, participants have rated L2 in between extreme warm and extreme cool whereas, L1 is having extreme warmth feeling and L3 is having extreme cool feeling. Therefore, it can be said that L2 i.e. CW LED with 100lux illumination level having moderate brightness and warm feelings helps to create a pleasurable display for oil-based paintings as well as water-based paintings.

Table 8.6- Mean value of participants' ratings for oil-based paintings

Factors	Mean ± SD		
	L1: WW LED, I_{50}	L2: CW LED, I_{100}	L3: AD LED, I_{150}
High Contrast	3.66±0.225	3.70±0.225	4.50±0.225
Warm	4.76± 0.190	4.06±0.190	2.40±0.190
Bright	2.80±0.203	3.76±0.203	4.86±0.203
Clear	3.46±0.223	4.60±0.223	4.50±0.223
Colourful	3.46±.240	4.40±.240	4.23±.240
Natural	3.90±0.252	4.33±0.252	3.06±0.252
Positive impact	3.53±0.220	4.56±0.220	3.40±0.220
Soft	3.83±0.253	4.13±0.253	3.20±0.253
Artistic	4.20±0.221	4.50±0.221	2.96±0.221
Lively	3.46±0.226	4.33±0.226	3.60±0.226
Comfortable	3.56±0.251	4.53±0.251	3.60±0.251
Pleasant	3.56±0.222	4.63±0.222	3.66±0.222

To support and verify the result derived from this qualitative study, the gaze duration of viewers has been analyzed statistically. Fig.8.2 shows the plot of gaze data for oil-based paintings. In the graph, X-axis represents different light parameters (CCT and Illuminance) and Y-axis represents the individual value of gaze data converted in fractional form.

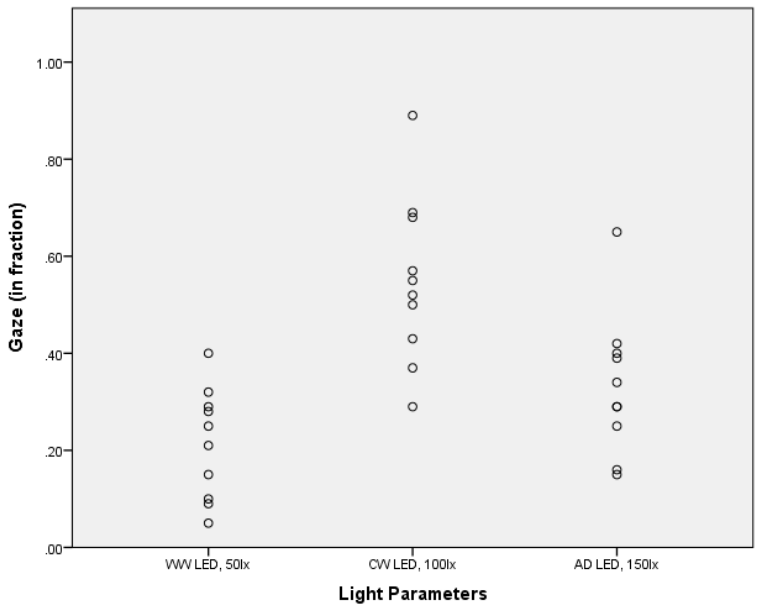

Fig.8.2. Plot of gaze data for oil-based paintings

From fig. 8.2 it can be observed that mean value of gaze duration for oil-based painting under CW LED with 100lux level (L2=0.55, SD=0.173) is more than mean value of gaze duration for oil-based painting under WW LED with 50lux level (L1 =0.21, SD=0.114) and AD LED with 150lux level (L3=0.33, SD=0.145). So, viewers have given more attention to oil-based painting exhibited under CW LED in 100 lux level than the painting exhibited under WW LED and AD LED with 50lux and 150lux level respectively. It depicts that though the paintings were identical but viewers have preferred viewing particularly under CW LED with 100 lux illumination level. Therefore, in accordance with the result derived from the qualitative study, this result also is revealing that best possible appearance of oil-based paintings could be achieved under CW LED having 100 lux light level on the plane of the paintings.

8.2.5 Effect of medium of paintings on viewers' perception:

Based on both the experimental results associated with water-based and oil-based paintings it can be assumed that the effect of light parameters (CCT and Illuminance) on viewers' perception while viewing paintings is similar irrespective of the medium of paintings. To verify this statement t-test has been done on common significant factors derived from the previous results (shown in Table 8.2 and Table 8.5). The result of this test is as shown in Table 8.7.

Table 8.7- t-test result for effect of medium of paintings

Dependent Variable	F-value	p-value
Warm*	2.768	.000
Bright*	4.910	.000
Clear*	6.549	.000
Natural	3.250	.103
Positive impact*	2.547	.001
Soft	1.681	.229
Artistic	0.110	.565
Comfortable*	13.470	.000
Pleasant*	4.011	.000

*indicates the factor is statistically significant ($p<0.05$)

Table 8.7 depicts that some of the factors (6 factors) considered in this study significantly depend on the medium of the paintings. Therefore, the assumption that the effect of light parameters on viewers' perception while viewing paintings is similar irrespective of the medium of paintings cannot be stated. However, from the experimental result, it can be stated that (table 8.3 and table 8.6) in view of the best possible appearance of painting viewers have preferred CW LED and I_{100} combination for both mediums of paintings.

8.3 **Discussion:**

The experimental results to understand the preferred combination of CCT and Illuminance while viewing paintings exhibited under LED lights is suggesting that viewers have preferred the combination of 3500K CCT and 100 lux illumination level for viewing both types of paintings considered in this study. In addition, this experimental result depicts that instead of preferring lower CCT at low illuminance or higher CCT at high illuminance [45], viewers have preferred mostly medium CCT (that lies between warm white to artificial daylight) with medium illumination level. Therefore, in accordance with the earlier study [62], this study also anticipates that Kruithof's graph [44] recommendation for preferred CCT and Illuminance may not be suitable for LED lighting for viewing paintings. Further, in view of earlier researcher [78], it can be stated that as Kruithof study was validated for general room illumination, therefore, it can be ignored for viewing any particular object, in this case paintings.

The experimental findings from factor analysis reveals that there are three dominating visual factors: 'pleasantness' (including scales of comfortable, pleasant, relaxed, positive impact, soft, lively, artistic, natural and high quality), 'brightness' (high contrast, bright, clear and colourful) and 'warmth' (warm). These three determine the effect of CCT and Illuminance on visual perception for observing paintings as shown in fig.8.3.

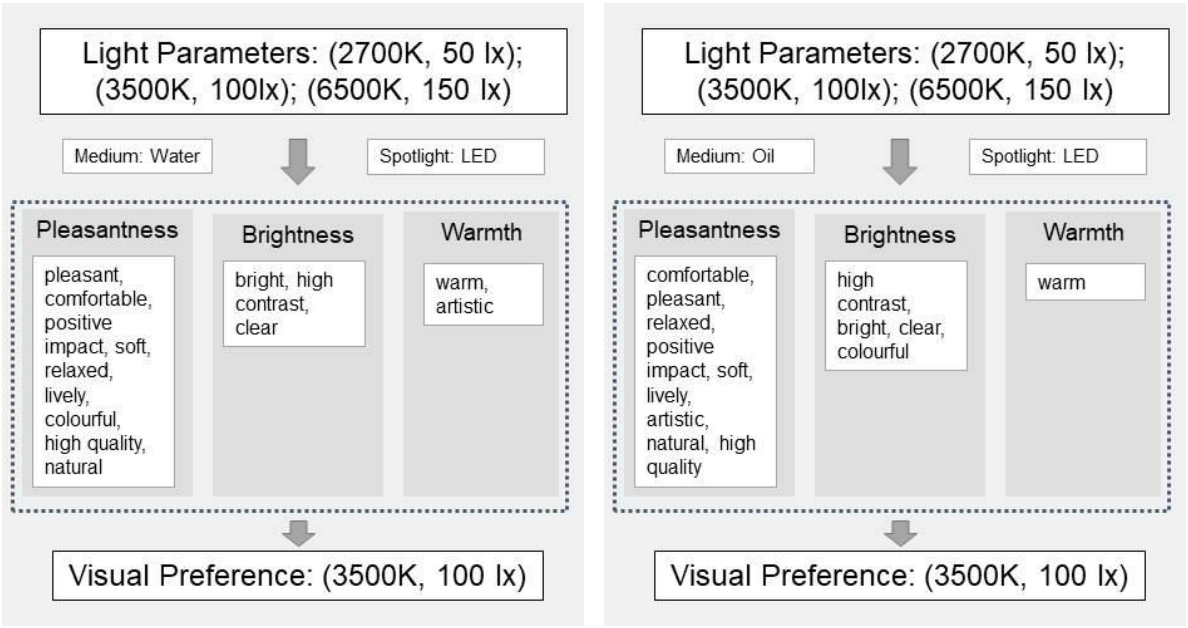

Fig. 8.3. Effect of CCT and Illuminance on visual perception

From the data of viewers' gaze duration on paintings, it has been seen that participants have given more attention to paintings exhibited under CW LED with 100lux Illuminance than other two light setups. In addition, for both medium of paintings, in comparison to other two lighting setups, CW LED with 100lux Illuminance has appeared to be more pleasant to the viewers for its moderately warm and bright effect on the appearance of paintings. As these feelings are very much subjective, so, in different atmospheric conditions viewers may perceive it differently. For example, the warm feelings of viewers in tropical countries may not match with the viewers from the non-tropical region. The key findings and implications of the present study have been discussed in the next chapter.

Chapter- 9
Conclusion

This final chapter discusses conclusions obtained from the findings from two phases of the study, the field study and laboratory-based experiments. This chapter starts by summarizing the key findings of the whole study. Then, it develops a lighting design approach for effective spotlight design in painting exhibition based on visual preferences. Successively, the chapter discusses the potential implications of this study in design research and education. The limitations of the study are mentioned in the end to identify the future research scope of the present study.

9.1 Summary of Key Findings:

The study was designed to fulfill the research objectives discussed in chapter 2. The outcomes of the study are summarized below.

- To understand the existing lighting scenario for exhibiting paintings in galleries of India a lighting survey in selected art galleries of India was conducted. It was found that lighting has not been arranged considering the viewers' perspective. In continuation, interviews with famous painters/ visual artists of India were conducted to understand the views of painters on present lighting conditions. Painters have found lighting condition in galleries of India unsatisfactory. Successively, to understand the lighting design process and expectation of exhibition stakeholders, interviews were conducted with curators/ exhibition designers and lighting professionals. It was found that there exist contradictions between gallery personnel and lighting professionals in the views of the lighting design process.

- To understand the impact of different types of spotlight on viewers' perception while viewing paintings an experiment was carried out by keeping other light parameters (CCT and Illuminance) at constant. Through this experiment, constructed hypothesis (H1) was tested and verified. Experimental results suggest that the perception of viewers depends on types of spotlight under which paintings are being exhibited.

- To understand the effect of CCTs on viewers' perception while viewing paintings, an experiment was carried out by keeping other light parameters (type of light and Illuminance) at constant. Through this experiment, constructed hypothesis (H2) was tested and verified. Experimental results suggest that the perception of viewers depends on lamp CCTs under which paintings are being exhibited.

- To understand the effect of Illuminance on viewers' perception while viewing paintings, an experiment was carried out by keeping other light parameters (type of light and CCT) at constant. Through this experiment, constructed hypothesis (H3) was tested and verified. Experimental results suggest that the perception of viewers changes due to different illumination levels under which paintings are being exhibited.

- To find out viewers' preferred combination of lighting parameters (CCT and Illuminance) for viewing paintings an experiment was conducted. The experimental results suggest that viewers have preferred the combination of 3500K CCT and 100 lux illumination level for viewing paintings under LED spotlight.

Therefore, combining the findings from laboratory-based experiments, the visual preference for effective spotlight design in painting exhibition can be modelled as shown in fig. 9.1.

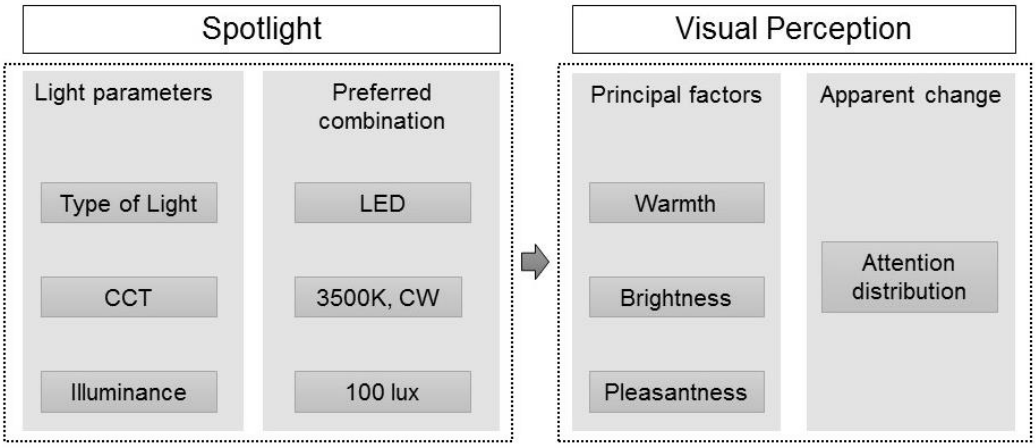

Fig. 9.1. The model of visual preference for effective spotlight design in painting exhibition

Based on this model (fig. 9.1) a lighting design (spotlight) approach has been developed for optimizing the lighting conditions in art galleries of India based on visual preferences.

9.2 Lighting Design Approach for Art Galleries:

Based on the interaction with painters, curators, exhibition designers and lighting professionals and also from experimental results it can be said that there is a mismatch between the practical scenario and required lighting set up. Therefore, to mitigate the gaps between viewers, designers, painters and lighting professionals lighting design approach has been framed (as shown in fig.9.2) for optimizing the lighting conditions in art galleries of India from viewers' perspective.

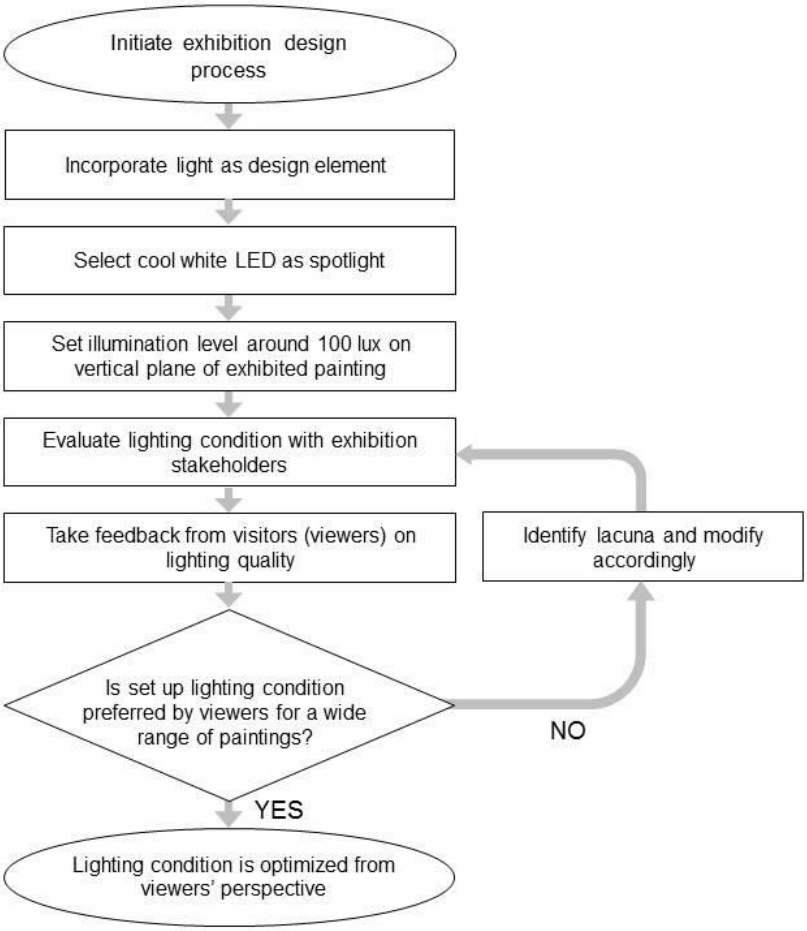

Fig.9.2. Lighting design (spotlight) approach in art galleries

In this lighting design approach type of light, CCTs and illumination levels have been selected based on the model (fig. 9.1) defining the effect of spotlights on visual perception. This model has been developed by assimilating the previous experimental results (chapter 5, chapter 6, chapter 7 and chapter 8). From the experimental results, it has been seen that for both the medium of paintings, in comparison to other two light setups, CW LED with 100 lux has appeared to be more pleasant having a moderately warm and bright effect on the appearance of paintings. It is expected that framed lighting design approach would serve the lighting designers of India to incorporate viewers' perspective at an early stage of lighting installation in art galleries.

9.3 Implication of study:

9.3.1 Design Practice:

This study provides a design approach to optimize the lighting condition in painting exhibition of India from the viewers' perspective. In spite of the advancement of lighting technology over the past century, light is most often applied to exhibition design as a functional additive rather than considered early in a project as an essential design element [98]. The novelty of the present study lies in the elicitation of a design approach that incorporates light as a design element in the early stage of exhibition design process. The

purpose of this lighting design approach is not to restrict but to emancipate lighting design for art galleries from specific guidelines.

This study has documented the views of painters on the lighting condition in galleries. Also, it has tried to bridge the gap among the stakeholders associated with exhibition lighting design. The study has avoided technical jargon to increase its accessibility to practitioners from diverse fields such as design, curatorship, visual art etc. When exhibition stakeholders have access to accurate information about the effect of certain lighting parameters on visual perception (such as visual quality, artefact appearance, visibility etc.), they can develop lighting design based on documented evidence rather than speculation [19].

9.3.2 Research and Education:

The findings of this study can assist exhibition designers and gallery personnel to introduce relevant curricula in their field of study to address existing lighting design issues in galleries. Moreover, designers and gallery personnel should be educated through design educational curricula about the light effect on visual perception for the betterment of appearance of paintings to the viewers. On the other hand, lighting professionals (engineers) need to realize the importance of pleasurable visual display for an art exhibition. Arguably, the research improvement in understanding human perception of brightness has the potential to lead towards a more energy efficient solution than conventional lighting guidance [99] [100]. By limiting the illumination level, a moderately bright appearance of painting can be created as described in the experimental result. Limitation of illumination level will certainly help to consume less energy than overexposed lighting condition. Therefore, this study will assist lighting professionals to take a holistic approach to create energy-efficient lighting design. Further, the study can contribute to the research related to the energy-efficient lighting design.

9.4 Limitations:

The findings of this study are applicable only to permanent painting exhibition galleries where lighting set up does not change with the theme of the paintings. Therefore, the framed design solution is referred to lighting designers who usually install light to any permanent gallery for a certain period (usually payback period) and have no scope to modify with exhibited artefacts. The limitations of this study are as follows.

- The study has not considered ambient light and cannot comment on target/ambient illumination ratio.
- The study has concentrated only on three parameters of light those have significant visual attribution. Other lighting issues (such as glare, beam angle, mean room surface exitance etc.) have not been considered.
- The experimental findings cannot comment on how the theme of painting influences participants' response.
- All the experiments were simulated in a laboratory space, not in real gallery.

- Only two mediums (water and oil) of paintings were considered in this study. Consideration of other medium may had have influence on visual perception.

Limitations of this study evoke several opportunities for future research.

9.5 Future Scope:

The findings and limitations identified in this study provide scope for further research in this area of interest. The future study should expand the lighting design objective in art galleries/museums by considering other light parameters as well as other artefacts of galleries/ museum. Studies should emphasize on the methodology to investigate the relationship between light and visual perception. Also, the present study method can be repeated in different tropical regions to understand the influence of climatic conditions on lighting preference of viewers. It is argued that lighting is not an art, not a science but rather a language [101] [102]. With this view, this present study creates a paradigm to interpret non-verbal expression such as visual perception. It is expected that the present study will ignite further study to relate language of light with visual perception of art.

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List of Publications

1. **A. Bhattacharjee**, S. Pal (2019). Effect of color temperature on appearance of paintings exhibited under LED lighting. Color Res Appl. Vol 44, pp. 762–771. https://doi.org/10.1002/col.22403

2. **A. Bhattacharjee,** S. Pal (2019)**.** Attention of Viewers While Viewing Paintings Changes with the Different CCTs of Exhibition Light: A Quantitative Approach with Eye-Tracking Method. In: Research into Design for a Connected World, Vol. 2, pp. 487-495, Smart Innovation, Systems and Technologies 135. Springer Nature Singapore Pte Ltd., ICoRD 2019.

3. **A. Bhattacharjee**, S. Pal (2019). Attention of Viewers While Viewing Paintings Depends on Different Types of Exhibition Light: A Quantitative Approach with Eye-Tracking Method. In: Advances in Ergonomics in Design, Vol. 777, pp.328-336, Advances in Intelligent Systems and Computing. Springer, AHFE 2018.

4. **A. Bhattacharjee**, S. Pal (2017). Review on Sustainable Lighting Design in Art Galleries to Balance between Visibility and Conservation of Light Sensitive Art Exhibits. In: Research into Design for Communities, Vol. 2, pp. 247-253, Smart Innovation, Systems and Technologies 66. Springer Nature Singapore Pte Ltd., ICoRD 2017.

Appendices

Appendix I
Questionnaire for Experiments

Name:

Age:

Gender:

Educational/ Professional background: Design/ Fine Arts/ Architecture

Frequency of exhibition visit: Very frequent/moderately frequent/ sometimes/ very few times

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You have seen paintings under different lighting conditions. Now, please rank the **appearance of paintings due to light** according to your choice.

The following factors (14 **opposite pairs**) have to be ranked based on **appearance of Watercolour paintings due to light.** Rank it from **1 to 6** (e.g. **1: extremely Low-Contrast, 2: moderately Low-Contrast, 3: little Low-Contrast, 4: little High-Contrast, 5: moderately High-Contrast, 6: extremely High-Contrast**).

	Painting marked as 1						
Factors	**1**	**2**	**3**	**4**	**5**	**6**	Factors
Low-Contrast							**High-Contrast**
Cool							**Warm**
Dimmed							**Bright**
Unclear							**Clear**
Dull							**Colourful**
Artificial							**Natural**
Low-Quality							**High-Quality**
Negative impact							**Positive impact**
Tense							**Relaxed**
Hard							**Soft**
Merchandise							**Artistic**
Boring							**Lively**
Uncomfortable							**Comfortable**
Unpleasant							**Pleasant**

Painting marked as 2							
Factors	1	2	3	4	5	6	Factors
Low-Contrast							**High-Contrast**
Cool							**Warm**
Dimmed							**Bright**
Unclear							**Clear**
Dull							**Colourful**
Artificial							**Natural**
Low-Quality							**High-Quality**
Negative impact							**Positive impact**
Tense							**Relaxed**
Hard							**Soft**
Merchandise							**Artistic**
Boring							**Lively**
Uncomfortable							**Comfortable**
Unpleasant							**Pleasant**

Painting marked as 3							
Factors	1	2	3	4	5	6	Factors
Low-Contrast							**High-Contrast**
Cool							**Warm**
Dimmed							**Bright**
Unclear							**Clear**
Dull							**Colourful**
Artificial							**Natural**
Low-Quality							**High-Quality**
Negative impact							**Positive impact**
Tense							**Relaxed**
Hard							**Soft**
Merchandise							**Artistic**
Boring							**Lively**
Uncomfortable							**Comfortable**
Unpleasant							**Pleasant**

Remarks (if any):

The following factors (14 **opposite pairs**) has to be ranked based on **appearance of Oil paintings due to light.** Rank it from **1 to 6** (e.g. **1: extremely Low-Contrast, 2: moderately Low-Contrast, 3: little Low-Contrast, 4: little High-Contrast, 5: moderately High-Contrast, 6: extremely High-Contrast**).

Painting marked as 1							
Factors	**1**	**2**	**3**	**4**	**5**	**6**	Factors
Low-Contrast							**High-Contrast**
Cool							**Warm**
Dimmed							**Bright**
Unclear							**Clear**
Dull							**Colourful**
Artificial							**Natural**
Low-Quality							**High-Quality**
Negative impact							**Positive impact**
Tense							**Relaxed**
Hard							**Soft**
Merchandise							**Artistic**
Boring							**Lively**
Uncomfortable							**Comfortable**
Unpleasant							**Pleasant**

Painting marked as 2							
Factors	**1**	**2**	**3**	**4**	**5**	**6**	Factors
Low-Contrast							**High-Contrast**
Cool							**Warm**
Dimmed							**Bright**
Unclear							**Clear**
Dull							**Colourful**
Artificial							**Natural**
Low-Quality							**High-Quality**
Negative impact							**Positive impact**
Tense							**Relaxed**
Hard							**Soft**
Merchandise							**Artistic**
Boring							**Lively**
Uncomfortable							**Comfortable**
Unpleasant							**Pleasant**

Painting marked as 3							
Factors	**1**	**2**	**3**	**4**	**5**	**6**	Factors
Low-Contrast							**High-Contrast**
Cool							**Warm**
Dimmed							**Bright**
Unclear							**Clear**
Dull							**Colourful**
Artificial							**Natural**
Low-Quality							**High-Quality**
Negative impact							**Positive impact**
Tense							**Relaxed**
Hard							**Soft**
Merchandise							**Artistic**
Boring							**Lively**
Uncomfortable							**Comfortable**
Unpleasant							**Pleasant**

Remarks (if any):

Appendix II
Consent Form for Participants

Purpose of experiment: To verify the light effect on viewers' perception when viewing paintings

Investigator: Ms Amrita Bhattacharjee (PhD Research Scholar, IIT Guwahati)

Please read the points below and sign in the space below to provide your informed consent to participate in the experiment.

- You will not be identified in the study or final report.
- Your responses will be confidential and any information provided will only be used for the purposes of this research and other academic platform.
- You are free to withdraw your participation at any time without penalty.
- You will receive no financial benefits for your participation beyond receipt of a gift as token.

I _____ have read and understand this informed consent sheet and agree to participate in this experiment.

Signed _____
Date:

Appendix III
Interviews with Painters

(Names are not disclosed due to ethical reason)

Instruction: Please select (Put Tick '√' mark in the corresponding box) **any one** from **each opposite pair of factors** according to your **preference on appearance of painting due to effect of lighting** in exhibition. Please share your thoughts for your choice of preference for each pair of factors.

Professional background: Painter

Dominant base medium of painting: Water

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast √	High-Contrast	High contrast light bounces unevenly from the painting due to the variation of colour depth in the painting. For example, in acrylic painting, there is a huge variation of colour depth and contrast in light diminishes the colour appearance. Uniformly distributed light with low-contrast is preferable.
	Cool √	Warm	Warm light changes the colour appearance of painting.
	Dimmed √	Bright	Bright light diminishes the essence of the painting.
	Artificial	Natural √	Natural light like daylight
Effect of light on exhibition atmosphere	Hard	Soft √	Soft like diffused daylight
	Merchandise	Artistic √	Merchandise light diminishes the essence of the painting exhibition.
Other factor(s) (if any)	Illuminance		Level of illumination is generally high than required in art galleries for exhibition.
Comments (if any): Artificial light in art galleries should be like evenly distributed daylight with low-brightness. The light in exhibition should help to percept the paintings to the viewer as it is like when it was made. Light should not change the colour appearance of painting to the viewer from the original one.			

Professional background: Visual artist/Painter

Medium: Mixed media

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast √	High-Contrast	Set light as per painting
	Cool	Warm √	Warm light is preferable.
	Dimmed √	Bright	Low ambient light is preferable.
	Artificial √	Natural	International galleries give artificial lights according to painters' choice.
Effect of light on exhibition atmosphere	Hard	Soft √	Soft lighting is preferable.
	Business	Artistic √	Ambient should be artistic.
Other factor(s) (if any)	----		
Comments (if any): Like to work with LED lights.			

Professional background: Painter

Medium: Watercolour and Oil Pastels

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast√	High-Contrast	Light should accompany the feelings of painting.
	Cool	Warm√	Little warm light is preferable.
	Dimmed	Bright√	I prefer bright lighting, as colours in my paintings are also bright.
	Artificial	Natural√	The painting should look natural as it was painted.
Effect of light on exhibition atmosphere	Hard	Soft√	Hard lighting diminishes the essence of painting.
	Merchandise	Artistic√	The whole environment should be artistic.
Comments: Light must create mood of the painting. Combination of yellow and white light is desirable for the exhibition. The lighting conditions in most of the galleries of India are not satisfactory.			

Professional background: Painter

Medium: Pen and ink on paper

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast √	High-Contrast	It goes as per my subject of painting.
	Cool √	Warm	Cool as natural daylight.
	Dim √	Bright	Subject of my painting requires less bright light.
	Artificial	Natural √	Natural like daylight.
Effect of light on exhibition atmosphere	Hard	Soft √	Both as viewer and painter soft light on painting is preferable.
	Business	Artistic √	Environment should be artistic for the sake of painting.
Other factor(s) (if any)	Angle of light		Sometimes painting need light from different angle.
Comments (if any): Lighting position should be arranged properly so that it will focus on painting not to the wall. Lighting condition in art galleries of India is not at all satisfactory. Light effect on paintings is too bright in most of the cases. Also, warm light is not preferable.			

Professional background: Painter

Medium: Acrylic on canvas

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast √	High-Contrast	The contrast between background wall and painting should be low. Light should focus on painting not to the wall.
	Cool √	Warm	Light should be cool as daylight.
	Dim √	Bright	Too much bright light diminishes the essence of painting.
	Artificial	Natural √	The light on painting should be natural like daylight.
Effect of light on exhibition atmosphere	Hard	Soft √	Hard lighting diminishes the appearance of painting.
	Business	Artistic √	Environment should be artistic.
Other factor(s) (if any)	Viewing distance from painting		Lighting should be arranged according to the viewing distance from painting.
Comments (if any): There should not be any reflection from light. Light on painting should not make any disturbance to the viewer while viewing.			

Professional background: Painter

Medium: Acrylic on canvas

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast √	High-Contrast	High contrast is not good for exhibition of painting.
	Cool	Warm √	Subject of my painting requires warm light.
	Dim √	Bright	Dim light helps to connect with the environment.
	Artificial √	Natural √	Depends on the subject of the painting.
Effect of light on exhibition atmosphere	Hard	Soft √	Appearance of painting becomes good.
	Business	Artistic √	Environment should look artistic.
Other factor(s) (if any)	Colour of light		Sometimes painting need different colour of light than usual light colour in galleries.
Comments (if any): Lighting design in art galleries should be more emphasized which has lack of proper thinking.			

Professional background: Painter/ Graphic Designer

Medium: Acrylic

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast √	High-Contrast	Light should be blended with the colour of painting. So, low contrast is preferable.
	Cool √	Warm	Light must be cool for all exhibition.
	Dim √	Bright	Dim light particularly focused on painting.
	Artificial	Natural √	Subject of my painting needs natural light like daylight.
Effect of light on exhibition atmosphere	Hard	Soft √	Hard light is not acceptable.
	Business	Artistic √	It helps to create the atmosphere for painting exhibition.
Other factor(s) (if any)	----		
Comments (if any): Light with low brightness should be properly focused on painting only. Bright distributed light destroys the appearance of painting.			

Professional background: Painter/Visual artist / Multidisciplinary artist

Medium: Acrylic paint

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast √	High-Contrast	Evenly distributed low contrast light
	Cool √	Warm	Light should give a cool soothing effect to environment.
	Dimmed √	Bright	Diffused light is preferable.
	Artificial	Natural √	Paintings should look like as it is under natural light.
Effect of light on exhibition atmosphere	Hard	Soft √	Soft lighting is desirable.
	Business	Artistic √	Lighting should create artistic ambient.
Other factor(s) (if any)	Light position : (Distance from painting/ print)		Light should be positioned from a considerable distance instead of too close to the artwork.
Comments (if any): Diffused ambient light with less warm effect is desirable.			

Professional background: Painter

Medium: Acrylic on canvas

Basis	Factors		Please share views on your selection
Effect of light on appearance of painting	Low-Contrast √	High-Contrast	Colours of painting can be properly seen.
	Cool √	Warm	It helps to improve viewer's perspective.
	Dim √	Bright	Dim light helps to create good environment.
	Artificial	Natural √	Every painting needs natural light like daylight. It gives natural feelings to viewer.
Effect of light on exhibition atmosphere	Hard	Soft √	Appearance of painting becomes good.
	Business	Artistic √	Environment should look artistic.
Other factor(s) (if any)	----		
Comments (if any): We have no option to change the colour of light according to the subject while exhibiting in the galleries.			

Appendix IV
Interviews with Exhibition Stakeholders

(Names are not disclosed due to ethical reason)

Profession: Curator

Job experience: 30 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Among these following factors which are in consideration while installing light for art exhibition in gallery?

√	International/ Indian recommended standards for art gallery lighting
√	Lighting for betterment of visual appearance of artifacts
	Implementation of advanced light sources (e.g. transition from incandescent to LED)
√	Lighting sources with lower damage potential compared to other conventional lighting for preservation of artifacts
	Save energy and reduce cost/ maintenance
Please share your views (if any): Artifacts should be protected from excessive light levels, and especially from sunlight and florescent light, which contain high amounts of ultraviolet radiation.	

2. What are the predominant light sources presently are in use in galleries?

	LED
√	Compact fluorescent
	Linear fluorescent
	Incandescent
	Tungsten Halogen
Please share your views (if any): Presently most of the galleries in India are using CFL for save energy / reduce cost.	

3. Does lighting design change accordingly with exhibited artworks?

√	Yes
	No
	Sometimes
Please share your views (if any): Lighting arrangement require as per object display. Too much light speeds deterioration of photographs, textiles and printed or handwritten paper, furniture, etc.	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

	Material composition of artwork
√	Colour composition of artwork
√	Theme of the art exhibition
Please share your views (if any):	

5. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

√	Types of light
	Colour temperature [cool/warm]
√	Illumination level
Please share your views (if any): Display paper away from sunlight or florescent light. Light will cause the surface coatings, such as ink, to fade and (if the paper has a high acid content) will hasten the deterioration of the paper.	

6. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

√	Yes
	No
Please share your views (if any):	

7. If the answer of the previous question is 'Yes' then, whom did you interview for reactions to lighting?

	Gallery staff
√	Lighting professionals
	Visitors
	Artists
	Others(if any):

Q8 to Q10 are open-ended questions. Kindly share your views.

8. Which type of light source you prefer/ recommend for art exhibition and why?

Please share your views: If the LED on offer has a CRI of between 85 and 90 it can be described as having 'good colour rendering'. 90 and above is 'excellent colour rendering' and artwork to look at its comfortable visual. However, it depends on art objects condition.

9. In practical, while installing lighting for exhibition design, how much importance is being given to the viewer's preference for viewing artworks?

Please share your views: Priority should be given on comfortable visual and also due importance to the objects, it should not deteriorate because of the lighting arrangement.

10. In a summary, practically how lighting design in any exhibition is being conducted and monitored?

Please share your views: Present day most of the art galleries are using of LED lighting system.

Profession: Curator, Freelance Art Writer

Job experience: 8 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Among these following factors which are in consideration while installing light for art exhibition in gallery?

	International/ Indian recommended standards for art gallery lighting
√	Lighting for betterment of visual appearance of artifacts
√	Implementation of advanced light sources (e.g. transition from incandescent to LED)
√	Lighting sources with lower damage potential compared to other conventional lighting for preservation of artifacts
	Save energy and reduce cost/ maintenance
Please share your views (if any):	

2. What are the predominant light sources presently are in use in galleries?

√	LED
	Compact fluorescent
	Linear fluorescent
	Incandescent
√	Tungsten Halogen
Please share your views (if any): Depends on the kind of ambience the curator is looking for also depends on the art works that are on display.	

3. Does lighting design change accordingly with exhibited artworks?

√	Yes
	No
	Sometimes
Please share your views (if any):	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

√	Material composition of artwork
√	Colour composition of artwork
√	Theme of the art exhibition
Please share your views (if any):	

5. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

√	Types of light
√	Colour temperature [cool/warm]
	Illumination level
Please share your views (if any):	

6. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

√	Yes
	No
Please share your views (if any):	

7. If the answer of the previous question is 'Yes' then, whom did you interview for reactions to lighting?

	Gallery staff
	Lighting professionals
√	Visitors
√	Artists
	Others(if any):
Please share your views (if any):	

Q8 to Q10 are open-ended questions. Kindly share your views.

8. Which type of light source you prefer/ recommend for art exhibition and why?

Please share your views: Lighting that the artwork demands, needs and also keeping in mind the ambiance.

9. In practical, while installing lighting for exhibition design, how much importance is being given to the viewer's preference for viewing artworks?

Please share your views: very important. Also because the viewer includes art critics, art buyers and collectors, hence it very important to keep in mind the visitors.

10. In a summary, practically how lighting design in any exhibition is being conducted and monitored?

Please share your views: we have an entire team who specializes and works according to the requirement.

Profession: Curator and Art critic

Job experience: 5 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Among these following factors which are in consideration while installing light for art exhibition in gallery?

√	International/ Indian recommended standards for art gallery lighting
√	Lighting for betterment of visual appearance of artifacts
	Implementation of advanced light sources (e.g. transition from incandescent to LED)
	Lighting sources with lower damage potential compared to other conventional lighting for preservation of artifacts
	Save energy and reduce cost/ maintenance
Please share your views (if any): Artifacts should be protected from excessive light levels, and especially from sunlight and florescent light, which contain high amounts of ultraviolet radiation.	

2. What are the predominant light sources presently are in use in galleries?

	LED
√	Compact fluorescent
	Linear fluorescent
	Incandescent
	Tungsten Halogen
Please share your views (if any): Presently most of the galleries in India are using CFL for save energy / reduce cost.	

3. Does lighting design change accordingly with exhibited artworks?

	Yes
	No
√	Sometimes
Please share your views (if any): Lighting arrangement require as per object display. Too much light speeds deterioration of photographs, textiles and printed or handwritten paper, furniture, etc.	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

	Material composition of artwork
	Colour composition of artwork
	Theme of the art exhibition
Please share your views (if any):	

5. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

	Types of light
	Colour temperature [cool/warm]
√	Illumination level
Please share your views (if any): Display paper away from sunlight or florescent light. Light will cause the surface coatings, such as ink, to fade and (if the paper has a high acid content) will hasten the deterioration of the paper.	

6. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

	Yes
√	No
Please share your views (if any):	

7. If the answer of the previous question is 'Yes' then, whom did you interview for reactions to lighting?

	Gallery staff
	Lighting professionals
	Visitors
	Artists
	Others(if any):

Q8 to Q10 are open-ended questions. Kindly share your views.

8. Which type of light source you prefer/ recommend for art exhibition and why?

Please share your views: Spotlight, Gallery wash

9. In practical, while installing lighting for exhibition design, how much importance is being given to the viewer's preference for viewing artworks?

Please share your views: The main objective is to make the works presentable.

10. In a summary, practically how lighting design in any exhibition is being conducted and monitored?

Please share your views: Lighting design as such is not very important in India. It is taken care almost at the end of the installation, just to illuminate the works. The importance is not given to understand the role of the artificial light and how natural light function in these spaces. Curators are also not adequately equipped to handle this issue.

Profession: Cultural Management Professional

Job experience: 10 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Among these following factors which are in consideration while installing light for art exhibition in gallery?

	International/ Indian recommended standards for art gallery lighting
√	Lighting for betterment of visual appearance of artifacts
	Implementation of advanced light sources (e.g. transition from incandescent to LED)
√	Lighting sources with lower damage potential compared to other conventional lighting for preservation of artifacts
	Save energy and reduce cost/ maintenance
Please share your views (if any):	

2. What are the predominant light sources presently are in use in galleries?

√	LED
	Compact fluorescent
	Linear fluorescent
	Incandescent
√	Tungsten Halogen
Please share your views (if any):	

3. Does lighting design change accordingly with exhibited artworks?

√	Yes
	No
	Sometimes
Please share your views (if any):	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

√	Material composition of artwork
√	Colour composition of artwork
√	Theme of the art exhibition
Please share your views (if any): All three factors are to be taken account, but primarily light designing is also about creating a narrative in support of the exhibition's theme.	

5. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

	Types of light
√	Colour temperature [cool/warm]
√	Illumination level
Please share your views (if any):	

6. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

√	Yes
	No
Please share your views (if any):	

7. If the answer of the previous question is 'Yes' then, whom did you interview for reactions to lighting?

	Gallery staff
√	Lighting professionals
√	Visitors
√	Artists
	Others(if any):

Q8 to Q10 are open-ended questions. Kindly share your views.

8. Which type of light source you prefer/ recommend for art exhibition and why?

Please share your views: I would prefer LED with CRI of RA 80 up.

9. In practical, while installing lighting for exhibition design, how much importance is being given to the viewer's preference for viewing artworks?

Please share your views: I feel any light design should create a complimenting narrative for the exhibition and thus the designer must understand what needs to be shown and what needs to be pushed back to near invisibility, For the viewer even the darkness and the shadows are to be carefully created. So light designing is always a matter of choice for the organizer and the artist.

10. In a summary, practically how lighting design in any exhibition is being conducted and monitored?

Please share your views: I am sure there are different standards for different institutions and galleries but for me the ideal would be to have a full drawn plan of the light design while planning the installation. Installation and light designing plan both needs to happen together or else it might end up being flat and unintentionally conflicting. There is a common practice in Indian galleries to put up an overall generic light when there are less number of visitors. This shows that light designing is not significant enough for many galleries. Converting from tungsten to LED gives an expensive yet one time solution to this need to rationing. As a matter of fact the practice of light designing shouldn't end with the exhibition only, designers should also guide the collectors and buyers to properly display the work in which ever space they might decide to keep the artwork in display. Audience experience and movements is to be observed to understand whether the design has guided them to experience the exhibition as intended and to also find out what common patterns are coming from the audience which might help one to modify the design further. Overall light designing is dependent on many factors and each factor is guided by multiple constrains and liberties. Somewhere in-between these constrains and liberties one has to find the balance of being non-intrusive but then again each design is defined by its defiance than compliance to the standards.

Profession: Director of Museum

Job experience: 28 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Among these following factors which are in consideration while installing light for art exhibition in gallery?

√	International/ Indian recommended standards for art gallery lighting
√	Lighting for betterment of visual appearance of artifacts
	Implementation of advanced light sources (e.g. transition from incandescent to LED)
√	Lighting sources with lower damage potential compared to other conventional lighting for preservation of artifacts
√	Save energy and reduce cost/ maintenance
Please share your views (if any): Now a days natural light along with artificial lighting, a judicious mixture of both is desirable, e.g. skylight proper ventilation and windows etc., but in India it's very rare.	

2. What are the predominant light sources presently are in use in galleries?

√	LED
√	Compact fluorescent
	Linear fluorescent
	Incandescent
	Tungsten Halogen
Please share your views (if any):	

3. Does lighting design change accordingly with exhibited artworks?

√	Yes
	No
	Sometimes
Please share your views (if any): It depends on the position of the gallery the exhibits etc.	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

√	Material composition of artwork
√	Colour composition of artwork
√	Theme of the art exhibition
Please share your views (if any):	

5. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

√	Types of light
√	Colour temperature [cool/warm]
√	Illumination level
Please share your views (if any):	

6. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

√	Yes
	No
Please share your views (if any): Guests do give advice about the overall impact of lighting.	

7. If the answer of the previous question is 'Yes' then,
   (a) Whom did you interview for reactions to lighting?

	Gallery staff
	Lighting professionals
√	Visitors
√	Artists
	Others(if any):
Please share your views (if any): Impact of light and shade on artefacts.	

Q8 to Q10 are open-ended questions. Kindly share your views.

8. Which type of light source you prefer/ recommend for art exhibition and why?

Please share your views: LED and natural, when both can be admixed properly.

9. In practical, while installing lighting for exhibition design, how much importance is being given to the viewer's preference for viewing artworks?

Please share your views: Curator and the Artist, previous responses of guests.

10. In a summary, practically how lighting design in any exhibition is being conducted and monitored?

Please share your views: Monitored by the Curator, some advice of artists are also welcome.

Appendix V
Interviews with Lighting Professionals

(Names are not disclosed due to ethical reason)

Profession: Regional application specialist

Job experience: 4 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Which guidelines/ recommendations are being followed for lighting design for art exhibition in galleries?

√	IES/ANSI: Rp-30 (Recommended Practices for Museums and Art Gallery Lighting
√	CIE 157:2004 (Control of Damage to Museum Objects by Optical Radiation
√	IS:3646-1 (1992): Code of practice for interior illumination
	Others: Please mention-
Comments (if any):	

2. Select the predominant light sources presently are in use in galleries.

	LED
	Compact fluorescent
	Linear fluorescent
	Incandescent
√	Halogen MR 16
	Others: Please mention-
Comments (if any):	

3. Does lighting design change accordingly with exhibited artworks?

√	Yes
	No
	Sometimes
Comments (if any)-	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

√	Medium of artwork
√	Theme of the art exhibition
√	Painter's preference
Please share your views (if any):	

5. Which factors are in consideration while installing light for art exhibition in gallery?

	Match with recommended standards for art gallery lighting
	Improve standard lighting for betterment of viewing
	Implementation of advanced light sources (e.g. transition from incandescent to LED)
√	Use lighting sources with lower/ equal damage potential compared to standard lighting
	Save energy and reduce cost/ maintenance
	Others: Please mention-
Comments (if any):	

6. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

√	Spectral power distribution (SPD)
√	Correlated colour temperature (CCT)
√	Illumination level
	Others: Please mention-
Comments (if any):	

7. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

	Yes
√	No
Comments (if any):	

8. If the answer of the previous question is 'Yes' then, whom did you interview for reactions to lighting?

	Gallery staff
	Lighting professionals
	Visitors
	Artists
	Others: Please mention-
Comments (if any):	

Q9 to Q11 are open-ended questions. Kindly share your views.

9. Which type of light source you prefer/ recommend for art exhibition and why?

Please mention- Halogen, LED.

10. What are the factors to be considered for lighting design in art exhibition?

Please mention- Spectral power distribution, lux requirement, minimal damage of art with respect to lighting position

11. How lighting design in any exhibition is being monitored?

Please mention- The designer needs to understand the type of painting and the Lux levels required for different types of painting like fabric painting, colour brush painting and so on. Also we need to understand the viewers thoughts before starting the design.

Profession: Associate manager

Job experience: 4 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Which guidelines/ recommendations are being followed for lighting design for art exhibition in galleries?

√	IES/ANSI: Rp-30 (Recommended Practices for Museums and Art Gallery Lighting
	CIE 157:2004 (Control of Damage to Museum Objects by Optical Radiation
	IS:3646-1 (1992): Code of practice for interior illumination
	Others: Please mention-
Comments (if any):	

2. Select the predominant light sources presently are in use in galleries.

	LED
	Compact fluorescent
	Linear fluorescent
√	Incandescent
√	Halogen MR 16
	Others: Please mention-
Comments (if any):	

3. Does lighting design change accordingly with exhibited artworks?

	Yes
√	No
	Sometimes
Comments (if any):	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

	Medium of artwork
	Theme of the art exhibition
	Painter's preference
Please share your views (if any):	

5. Which factors are in consideration while installing light for art exhibition in gallery?

	Match with recommended standards for art gallery lighting
	Improve standard lighting for betterment of viewing
√	Implementation of advanced light sources (e.g. transition from incandescent to LED)
	Use lighting sources with lower/ equal damage potential compared to standard lighting
√	Save energy and reduce cost/ maintenance
	Others: Please mention-
Comments (if any):	

6. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

√	Spectral power distribution (SPD)
√	Correlated colour temperature (CCT)
	Illumination level
	Others: Please mention-
Comments (if any):	

7. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

	Yes
√	No
Comments (if any):	

8. If the answer of the previous question is 'Yes' then, whom did you interview for reactions to lighting?

	Gallery staff
	Lighting professionals
	Visitors
	Artists
	Others: Please mention-
Comments (if any):	

Q9 to Q11 are open-ended questions. Kindly share your views.

9. Which type of light source you prefer/ recommend for art exhibition and why?

Please mention- LED.

10. What are the factors to be considered for lighting design in art exhibition?

Please mention- CCT

11. How lighting design in any exhibition is being monitored?

Please mention- By colour temperature

Profession: Assistant Manager

Job experience: 5 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Which guidelines/ recommendations are being followed for lighting design for art exhibition in galleries?

√	IES/ANSI: Rp-30 (Recommended Practices for Museums and Art Gallery Lighting
√	CIE 157:2004 (Control of Damage to Museum Objects by Optical Radiation
√	IS:3646-1 (1992): Code of practice for interior illumination
	Others: Please mention-
Comments (if any):	

2. Select the predominant light sources presently are in use in galleries.

	LED
	Compact fluorescent
	Linear fluorescent
	Incandescent
√	Halogen MR 16
	Others: Please mention-
Comments (if any):	

3. Does lighting design change accordingly with exhibited artworks?

√	Yes
	No
	Sometimes
Comments (if any):	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

	Medium of artwork
√	Theme of the art exhibition
	Painter's preference
Please share your views (if any):	

5. Which factors are in consideration while installing light for art exhibition in gallery?

√	Match with recommended standards for art gallery lighting
	Improve standard lighting for betterment of viewing
√	Implementation of advanced light sources (e.g. transition from incandescent to LED)
	Use lighting sources with lower/ equal damage potential compared to standard lighting
√	Save energy and reduce cost/ maintenance
	Others: Please mention-
Comments (if any):	

6. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

√	Spectral power distribution (SPD)
√	Correlated colour temperature (CCT)
√	Illumination level
	Others: Please mention-
Comments (if any): To beautify the theme of the gallery proper SPD, CCT and illuminance is required.	

7. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

√	Yes
	No
Comments (if any)-	

8. If the answer of the previous question is 'Yes' then whom did you interview for reactions to lighting?

√	Gallery staff
	Lighting professionals
	Visitors
	Artists
	Others: Please mention-
Comments (if any): Proper beam angle and CCT improve the lighting in the gallery. The maintenance work is also reduced.	

Q9 to Q11 are open-ended questions. Kindly share your views.

9. Which type of light source you prefer/ recommend for art exhibition and why?

Please mention- LED. Because prominent beam angle, various CCT and improved CRI with less power consumption recommends to use it.

10. What are the factors to be considered for lighting design in art exhibition?

Please mention- Various factors such as beam angle, CCT, CRI and placing of luminaire are to be considered for lighting design in art exhibition.

11. How lighting design in any exhibition is being monitored?

Please mention- Initially, the suitable type of light source is to be selected so that it doesn't impact on arts/painting and have proper CCT, CRI, beam angle and energy efficiency. After this selection, the luminaires are mounted on track/or recessed as per ceiling available in such a way that the arts/paints on the wall of the gallery can be seen properly with the consideration of proper beam angle. The luminaires should be able to rotate horizontally and vertically to illuminate properly the selected paints. Low maintenance luminaire will prolong the effects in the gallery. The CCT of the luminaires should not change over the time and for this proper-binned LED sources with SDCM < 3 is suitable.

Profession: Assistant manager

Job experience: 4 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Which guidelines/ recommendations are being followed for lighting design for art exhibition in galleries?

√	IES/ANSI: Rp-30 (Recommended Practices for Museums and Art Gallery Lighting
√	CIE 157:2004 (Control of Damage to Museum Objects by Optical Radiation
√	IS:3646-1 (1992): Code of practice for interior illumination
	Others: Please mention-
Comments (if any):	

2. Select the predominant light sources presently are in use in galleries.

√	LED
	Compact fluorescent
	Linear fluorescent
	Incandescent
	Halogen MR 16
	Others: Please mention-
Comments (if any):	

3. Does lighting design change accordingly with exhibited artworks?

	Yes
	No
√	Sometimes
Comments (if any)-	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

	Medium of artwork
	Theme of the art exhibition
	Painter's preference
Please share your views (if any):	

5. Which factors are in consideration while installing light for art exhibition in gallery?

√	Match with recommended standards for art gallery lighting
	Improve standard lighting for betterment of viewing
√	Implementation of advanced light sources (e.g. transition from incandescent to LED)
	Use lighting sources with lower/ equal damage potential compared to standard lighting
√	Save energy and reduce cost/ maintenance
	Others: Please mention-
Comments (if any):	

6. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

√	Spectral power distribution (SPD)
√	Correlated colour temperature (CCT)
√	Illumination level
	Others: Please mention-
Comments (if any): Appearance, Compactness of luminaires, how well it can be camouflage.	

7. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

	Yes
√	No
Comments (if any):	

8. If the answer of the previous question is 'Yes' then, whom did you interview for reactions to lighting?

	Gallery staff
	Lighting professionals
	Visitors
	Artists
	Others: Please mention-
Comments (if any):	

Q9 to Q11 are open-ended questions. Kindly share your views.

9. Which type of light source you prefer/ recommend for art exhibition and why?

Please mention- LED.

10. What are the factors to be considered for lighting design in art exhibition?

Please mention- CCT, illuminance

11. How lighting design in any exhibition is being monitored?

Please mention- By demonstration at site

Profession: Territory sales specialist

Job experience: 8 years

Please choose the options as per your decision and put '√' in the boxes where it is applicable.

1. Which guidelines/ recommendations are being followed for lighting design for art exhibition in galleries?

√	IES/ANSI: Rp-30 (Recommended Practices for Museums and Art Gallery Lighting
√	CIE 157:2004 (Control of Damage to Museum Objects by Optical Radiation
	IS:3646-1 (1992): Code of practice for interior illumination
	Others: Please mention-
Comments (if any):	

2. Select the predominant light sources presently are in use in galleries.

√	LED
	Compact fluorescent
	Linear fluorescent
	Incandescent
	Halogen MR 16
	Others: Please mention-
Comments (if any):	

3. Does lighting design change accordingly with exhibited artworks?

√	Yes
	No
	Sometimes
Comments (if any):	

4. If the answer of the previous question is 'Yes' then, based on which factors lighting design is to be changed?

	Medium of artwork
√	Theme of the art exhibition
√	Painter's preference
Please share your views (if any):	

5. Which factors are in consideration while installing light for art exhibition in gallery?

√	Match with recommended standards for art gallery lighting
	Improve standard lighting for betterment of viewing
√	Implementation of advanced light sources (e.g. transition from incandescent to LED)
	Use lighting sources with lower/ equal damage potential compared to standard lighting
√	Save energy and reduce cost/ maintenance
	Others: Please mention-
Comments (if any):	

6. At the time of lighting design for exhibition in gallery do the following factors are in consideration for visual appearance of artifacts?

	Spectral power distribution (SPD)
√	Correlated colour temperature (CCT)
	Illumination level
	Others: Please mention-
Comments (if any):	

7. Have you ever conducted any visual assessment of the lighting design from viewers' perspective?

	Yes
√	No
Comments (if any):	

8. If the answer of the previous question is 'Yes' then, whom did you interview for reactions to lighting?

	Gallery staff
	Lighting professionals
	Visitors
	Artists
	Others: Please mention-
Comments (if any):	

Q9 to Q11 are open-ended questions. Kindly share your views.

9. Which type of light source you prefer/ recommend for art exhibition and why?

Please mention- LED.

10. What are the factors to be considered for lighting design in art exhibition?

Please mention- CCT

11. How lighting design in any exhibition is being monitored?

Please mention- By Artist choice