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**Name of the Commentator/ Organization: _**

| **Part 11 Human Centric Lighting** | | |
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| **Clause No. with Para No. or Table No. or Figure No. commented (as applicable)** | **Comments / Modified Wordings** | **Justification of Proposed Change** |
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**(Lighting Code of India)**

# *Draft* NATIONAL LIGHTING CODE OF INDIA

# PART 11 HUMAN CENTRIC LIGHTING

## [First Revision of SP 72 (Part 11)]

**Illumination Engineering and Luminaries Sectional Committee, ETD 49**

**Last Date for Comments: 14 August 2024**

## FOREWORD

Light has a greater significance beyond its ability to facilitate vision, as it has a direct influence on the mood and sleep patterns. Additionally, it plays a crucial role in perception and acceptance of spatial surroundings. The conventional electric light sources are being replaced by digital LED technology at a rapid pace, which necessitates lighting professionals to incorporate new quality features into their designs, apart from managing physical variables like contrast and glare. The introduction of the Human Centric Lighting (HCL) approach emphasizes the importance of color temperature, intensity, illuminated materials, and human perception in optimizing the biological and emotional impact of light on individuals. In addition to its visual impact and power efficiency, HCL aims to enhance the overall health, well-being, and productivity of individuals through holistic planning and implementation of the visual, emotional, and biological impacts of light.

Light has two major effects on patterns of alertness and sleep. First, the timing of the circadian rhythm is synchronized by the 24-hour light-dark cycle, so daily exposure is required. Second, light is a stimulant and can increase alertness and performance.

## 1 SCOPE

This part deals with the health benefits, circadian rhythm, biological, psychological effects of Human Centric Lighting. It also includes approach, design, operation, applications of Human Centric Lighting in day-to-day life.

## 2 NORMATIVE REFRENCES

This part and section of the code is based on the following Standards:

| *IS Standard / International Standard* | *Title* |
|---|---|
| IS 3646 (Part 1):1992 | Code of practice for interior illumination: Part 1 general requirements and recommendations for working interiors (First Revision) |
| EN 12464-1: 2021 | Light and lighting - Lighting of work places - Part 1: Indoor work places |

## 3 TERMINALOGY

**3.1 Human Centric Lighting** — Human centric lighting (HCL) is lighting that enhances human experience, performance, health or wellbeing.

**3.2 Circadian Rhythm** — Circadian rhythm is the 24-hour internal clock in the brain that regulates cycles of alertness and sleepiness by responding to light changes in our environment.

**3.3 Body Clock** — Body clock is the internal biological mechanism which causes the body to automatically behave in particular ways at particular times of the day.

**3.4 Spectral Sensitivity** — Spectral sensitivity is the relative efficiency of detection, of light or other signal, as a function of the frequency or wavelength of the signal.

**3.5 Tunable Lighting** — Tunable white lighting technology is defined as the ability to control a light source's color temperature output.

## 4. BENEFITS OF HUMAN CENTRIC LIGHTING (HCL)

### 4.1 Importance to Health

The circadian system, often referred to as the "body clock," is responsible for regulating various biological functions in our body, including sleep, hunger, body temperature, blood pressure, and the release of sleep and stress hormones like melatonin and cortisol. When the circadian rhythm is well-coordinated, it optimizes the body's alertness, mood, and sleep cycle, leading to improved

sleep quality and better recovery. However, if there is a lack of synchronization or disruption to the circadian rhythm, it ~~can~~ result in decreased physiological functions, neurobehavioral performance, and sleep quality.

### 4.2 Human Body Clock

Light has an impact on the functioning of a human body. Three types of lighting needs have been identified that influences the peoples wellbeing.

**4.2.1** *Visual Need* — Needs which are to be appropriately fulfilled in order to perform the visual tasks.

**4.2.2** *Emotional Lighting Need* — Emotional light includes the right ambiance for a specific space, such as residential, retail, hospitality, office and road applications.

**4.2.3** *Biological Lighting Need* — This is extremely crucial for the people's wellbeing. Though everyone has been affected by this biological need since humanity is created, however it is studied and discovered very recently.

Recent research has revealed that light affects not only the rods and cones, but also a third receptor, which has been identified as the missing link in our understanding of how light impacts our health and wellbeing. This third receptor influences various hormones in the brain, including melatonin, which is produced in low light conditions or darkness, and cortisol, a stress hormone produced in higher light conditions. Medical scientists have discovered that approximately 1% of the ganglion cells in our retina, known as intrinsic photosensitive Retinal Ganglion Cells (ipRGCs), are sensitive to light. These cells are directly connected to the biological clock in the brain, which in turn regulates the release of certain hormones in body, including melatonin and cortisol. When light falls on the surface of these cells, it creates complex reactions and generates electrical impulses that are sent to the Suprachiasmatic Nuclei (SCN) biological clock. This clock is responsible for regulating our circadian (daily) and circannual (seasonal) rhythms.

### 4.3 Circadian Rhythm

The Earth's rotation around its axis takes precisely 24 hours, creating a 24-hour cycle of light and darkness. This cycle regulates various bodily processes, including the sleep-wake cycle, body temperature, heart rate, and the timing of hormone production. The Suprachiasmatic Nuclei (SCN) plays a significant role in regulating the sleep cycle and the production of cortisol, known as the stress or energy hormone, and melatonin, the sleep hormone. These hormones play a crucial role in controlling the body's alertness and sleep. Below Fig. 1 and Fig. 2 elaborates the typical rhythm of body temperature alongwith the variations of cortisol and melatonin during the cycle.

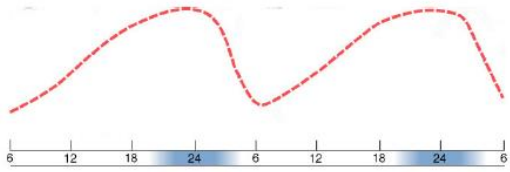


*Fig. 7.2 Double plot (2 x 24 hours) of typical daily rhythms of body temperature (relative scale).*

**Fig.1 Double Plot (2x24 hours) of Typical Daily Rhythms of Body Temperature (Relative Scale)**

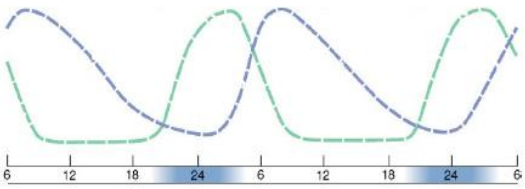


*Fig. 7.3 Double plot (2 x 24 hours) of typical daily rhythms of cortisol (blue) and melatonin (green) (relative scale).*

**Fig. 2Double Plot (2x 24 Hours) of Typical Daily Rhythms of Cortisal (Blue) And Melatonin (Green)**

In the morning, with the rise of the Sun, the body's cortisol (stress hormone) levels increase, preparing the body for the day's activities. Simultaneously, the sleep hormone melatonin levels drop,contributing to improved activity levels and alertness throughout the day. This natural hormonal shift influences the body's sleep-wake cycle.

Melatonin is responsible for inducing feelings of sleepiness and relaxation, while cortisol promotes wakefulness and activity. Consequently, humans are naturally inclined to sleep at night, and disruptions to this cycle, such as jet lag from traveling across time zones, can affect alertness and lead to feelings of sleepiness at inappropriate times. These hormonal fluctuations play a significant role in regulating overall sense of well-being throughout the day.

Working hours differ for every person according to their occupations. A person working at night needs to be awake in the night. He/she should be fit and alert enough to perform his task smoothly and without any adverse effect. The effects of nocturnal, morning, and evening light exposure on the hormone production, results in alertness/sleepiness and the synchronization of biological clock. Thus, for functions where people are expected to work at abnormal hours needs to be provided with appropriate lighting which will able to control hue, color, intensity etc. Lighting system is required to be designed in such a way that People working in those areas not only feel alert during duty hours but also able to adjust to their body clock once they are off duty. Biological lighting needs are fulfilled when the lighting supports the circadian rhythm, resulting in good sleep quality, and increases alertness or induces relaxation when needed. The main influential parameters seem to be light exposure (level and duration), spectrum, timing, and spatial distribution and size of the light source. Below Fig. 3 shows the spatial distribution of cortisol, melatonin, alertness, sleep cycle.

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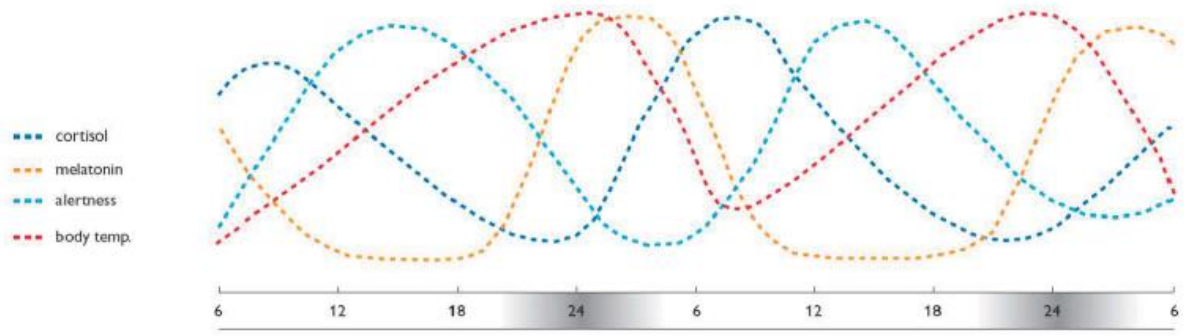


**Fig. 3. The Spatial Distribution of Cortisol, Melatonin, Alertness, Sleep Cycle.**

**4.3.1** *Non-visual Biological Spectral Sensitivity Curve* — The sensitivity of the intrinsic retinal cell also varies with different wavelengths. While observing the sensitivity curve, the difference in the visual sensitivity curve and non-visual biological sensitivity curve can be seen.

Fig. 4 shows the comparison of two curves, 'Visual' sensitivity curve for 'Photopic' region and 'Non-Visual' sensitivity curve. The peak of 'visual' sensitivity curve lies in Yellow-Green region and that of 'non-visual' sensitivity curve is in Blue region. Thus, light with high color temperature will be thus 'biologically' more effective than the source with low color temperature.

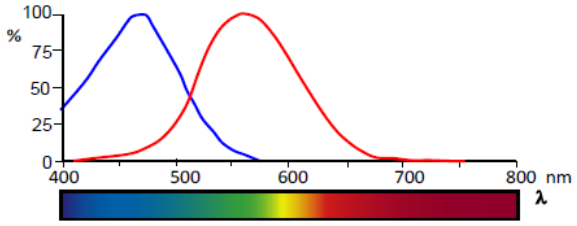


*Fig.7.4 Spectral non-visual biological sensitivity curve (based on melatonin suppression), in blue, and the visual eye-sensitivity curve V(λ), in red.*

**Fig. 4. Spectral Non-Visual Biological Sensitivity Curve Based on Melatonin Suppression.**

## 5 EFFECTS OF LIGHT ON HUMAN BODY

### 5.1 Biological Effects of Light

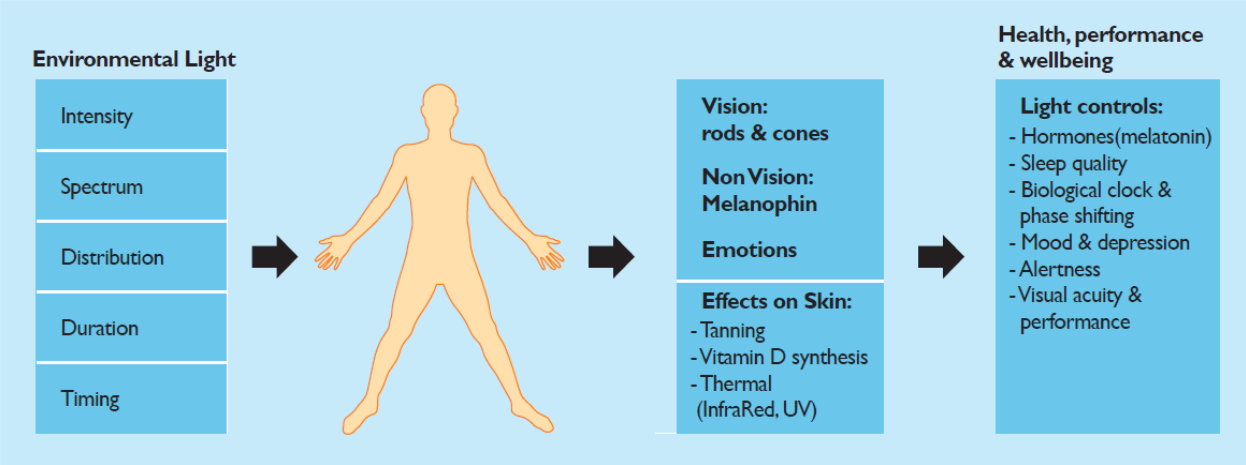


**Fig. 5 Effects of Light on Human Body**

Over the past few decades, significant advancements have been made in understanding the non-visual or non-image-forming effects of light, as depicted in the Fig. 5. These effects are partially mediated by melanopsin, a novel photoreceptor located in a specific type of retinal cell, which plays a crucial role in regulating the biological effects of light. Melanopsin is most responsive to blue light, with a peak sensitivity at 480 nm. When light is detected by these photoreceptor cells, a complex chemical reaction takes place, producing electrical impulses that are transmitted through separate nerve pathways to the biological clock, which governs the circadian and circannual rhythms of various bodily processes, including hormone production necessary for healthy sleep patterns. Therefore, lighting not only affects our vision, but it also has a profound impact on our overall health, well-being, alertness, and sleep quality.

### 5.2 Psychological Effects of Light

The psychophysical impacts of light are associated with the visual appeal, ambiance, and overall environmental factors (comprising luminance, luminance distribution, temporal dynamics, chromaticity, and chromaticity distribution within the visual field), which influence our psychological state, emotional experiences, motivation, and affective states.

## 6 HUMAN CENTRIC LIGHTING (HCL) APPROACH

Incorporating Human Centric Lighting (HCL) principles into a project requires early establishment and serves as a foundation for a comprehensive and collaborative planning process. Designers prioritize natural daylight utilization when possible. The lighting system is then installed and operated based on the HCL

plan. HCL implementation involves more than just adjusting illuminance and color temperature, as it considers the overall impact of lighting from a holistic perspective. This encompasses not only visual tasks and biological effects but also the situational context in which lighting is utilized.

### 6.1 Visual

Effective reception conditions are crucial for promoting workplace productivity. To meet this objective, normative and regulatory frameworks establish minimum standards for various activities and workspaces that facilitate visual tasks. The primary goal of the design and operation of these systems is to provide optimal visual conditions for workers. However, individual needs and preferences, such as increased lighting requirements for older adults, must be taken into consideration and customized accordingly.

### 6.2 Emotional

To promote human well-being within their social surroundings, various criteria based on architectural, aesthetic, perceptual psychology, and user expectations must be considered. These criteria adhere to interdisciplinary guidelines and best practices, as they cannot be quantified or found in relevant standards and regulations. Designing a visually appealing room with lighting and formal elements that meet users' expectations can lead to greater user acceptance, satisfaction, and overall well-being.

### 6.3 Biological

When designing lighting systems, careful consideration and planning of biological impacts is essential, as they significantly affect the human circadian rhythm. Properly planned lighting systems can support the need for increased productivity during the day and improved sleep quality at night. In some cases, lighting can also boost attentiveness and alertness for short period of time.

## 7 HUMAN CENTRIC LIGHTING (HCL) DESIGN AND OPERATION

When developing an HCL concept, a meticulous and conscientious planning process must take into account all possible effects of light, as they often intersect with one another. For instance, lighting designed to serve a specific visual task will also have biological and emotional impacts. Conversely, a design must not solely prioritize emotional or biological criteria, as it must also meet visual requirements while complying with normative and statutory regulations. Compared to conventional static lighting designs of the past, HCL concepts feature dynamic designs and a targeted, long-term perspective.

### 7.1 Planning Process

A successful HCL lighting concept requires a targeted and expert planning approach that considers the time-dependent effects of light on humans. This is achieved through the use of a light management system (LMS) that allows for personalized control and intelligent data collection. The inclusion of an HCL concept into a design presents a challenge for the designer, as it requires the consideration of parameters such as application usage, building, daylight situation, control, and

light technology. The user's specific requirements for the HCL solution must be assessed from an ergonomic, psychological, and biological perspective, and the designer shall develop a holistic concept based on this knowledge. Upon completion of the design phase, the designer creates a documentation package containing the necessary documents for implementing the HCL concept including lighting calculations, visualizations, data sheets, and light scenarios as illustrated in Fig. 6.

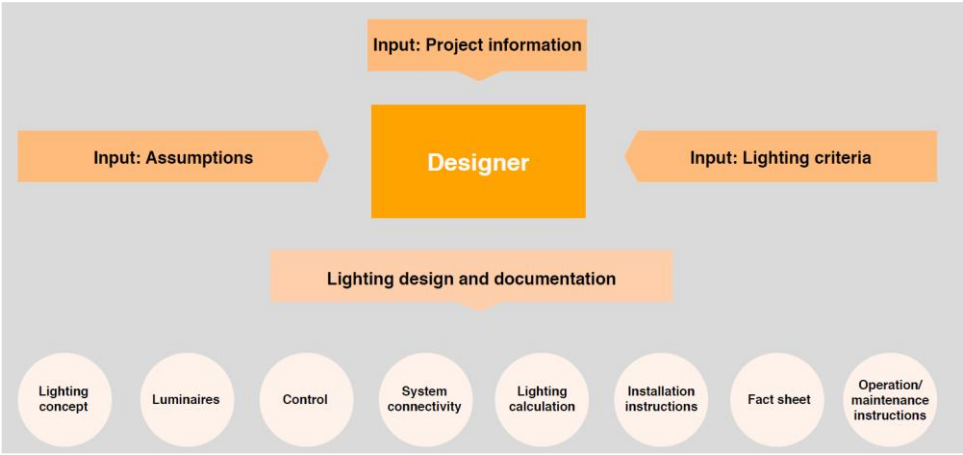


**Fig. 6. HCL System**

### 7.2 Planning Parameters

Planning parameters are important for creating a comprehensive and effective HCL lighting plan that meets the specific needs and requirements of the users. By considering factors such as the visual and work tasks of the users, their demographic characteristics, the characteristics of the building and rooms, the light technology and correlations, and the organization and control of the lighting system, the lighting designer can develop a plan that not only supports visual performance but also improves well-being and productivity.

For example, by taking into account the duration and chronological sequence of lighting, the lighting designer can create a plan that gradually adjusts the intensity and color temperature of light throughout the day to support the natural circadian rhythm of the users. By considering the surfaces and objects in the room, the lighting designer can ensure that light is directed to the appropriate areas and tasks while avoiding glare and shadows.

Furthermore, by incorporating advanced control systems, such as motion-dependent control and user-triggered scenarios, the lighting system can adapt to the changing needs and preferences of the users, providing a personalized and comfortable lighting experience.

In summary, by carefully considering these parameters, the lighting designer can create a human-centric lighting plan that enhances the well-being, productivity, and satisfaction of the users.

**7.2.1** *HCL Special Strategies* —It is crucial to emphasize the key strategies that distinguish Human Centric Lighting (HCL) from traditional lighting design approaches. However, it should be noted that simply applying these strategies in isolation does not necessarily constitute a human-centric approach.

**7.2.2** *Vertical Illumination* — Standards typically prioritize horizontal illumination, but vertical illumination is equally crucial yet frequently neglected in lighting design. Lighting vertical surfaces not only delineates space boundaries and proportions but also enhances perceived brightness and openness. Exclusive focus on horizontal surfaces may result in a dull atmosphere. Therefore, meticulous attention to vertical illumination is imperative. Utilizing wall-washers, up-lights, or tailored fixtures can effectively illuminate vertical surfaces and enrich the spatial ambiance.

**7.2.3** *Tunable Lighting* — Tunable white light is a valuable technology for human-centric lighting solutions. By dynamically adjusting a light source's color temperature and intensity, this lighting can enhance user comfort, productivity, and well-being. This adaptable lighting also promotes energy efficiency and cost savings. Tunable white light enables the creation of dynamic lighting environments that can accommodate varying needs and conditions, optimizing illumination throughout the day and night.

**7.2.4** *Glare Reduction* — The issue of high-efficacy LED light sources causing glare must be addressed by selecting appropriate glare-rated luminaires. For indoor applications, IS 3646 (Part 1) specifies a Unified Glare Rating (UGR) of less than 19, which is also essential for human-centric lighting.

### 7.3 Recommendations for Users and Effects

The fact sheet should also include details such as:

a) Description of the lighting design concept
b) Explanation of the control system and user interface
c) Guidelines for using presets and customization options
d) Instructions for adjusting light settings and creating new scenarios
e) Information on how light affects human well-being and productivity
f) Maintenance guidelines for the lighting system
g) Contact information for technical support and service requests.

A comprehensive fact sheet ensures users can maximize their lighting system's benefits and optimize it for their needs, promoting the advantages of human-centric lighting for daily life.

**7.3.1** *Recommendations* — Recommendations for optimal biological impact include maintaining an illuminance level between 300 to 500 lux on the eye throughout the entire workday. The lighting should also match daylight quality, with a color temperature exceeding 5,700 K until the early afternoon, and potentially shifting to 4000 K later in the day. It is recommended to use warm white

light with a color temperature of 2,700 K or a maximum of 3,000 K is specifically for applications where the goal is to reduce the biological impact of light on humans.

## 8. APPLICATIONS OF HUMAN CENTRIC LIGHTING

The lighting design should encompass architectural, aesthetic, and psychological aspects, supporting overall well-being. Following are few areas of applications of Human Centric Lighting:

### 8.1 Offices

Modern office environment requires a lighting system that is flexible, dynamic, and adaptable to the changing needs of the workspace. This means that the lighting system must adjust to varying levels of natural light and accommodate diverse activities. For instance, tunable white light can mimic daylight, providing suitable color and intensity for specific tasks. Lighting can also enhance the office's design, creating a visually appealing environment that boosts creativity and productivity. Moreover, lighting can promote employee well-being by regulating circadian rhythms and reducing the negative effects of artificial light on their eyes and sleep patterns.

Implementing an HCL lighting concept in modern offices can positively impact employee well-being and productivity, contributing to the workspace's success. The lighting design requirements outlined in Table 1 shall be considered for office spaces.

**Table 1 Lighting Design Requirements for Office Spaces**
(*Clause* **8.1**)

| **Sl. No.** | **Design Parameter** | **Lighting Basis / Approach** |
|---|---|---|
| (1) | (2) | (3) |
| i) | Visual tasks, concentration, communication, computer screen | Design as per EN 12464, IS 3646 |
| ii) | Flexible arrangement of workplaces | Achieve good uniformity, Low contrast, ensure Vertical illumination |
| iii) | Light as part of the workplace system | Minimum Glare |
| iv) | Ergonomics and health | Good color rendering, daylight integration with intelligent sensors |
| v) | Adjusting the lighting to time of day and year | Intelligent Lighting management system with tunability and central control |
| vi) | Adjusting the lighting to user’s individual needs | Intelligent Lighting management system with tunability and user interface |

### 8.2 Schools / Institutions

The lighting requirements outlined in Table 2 shall be considered for schools and Institutions.

**Table 2 Lighting Design Requirements for Schools / Institutions**
(*Clause* **8.2**)

| **Sl. No.** | **Design Parameter** | **Lighting Basis / Approach** |
|---|---|---|
| (1) | (2) | (3) |
| i) | Studying, reading, listening (presentation, projector, exercises) | Design as per EN 12464, IS 3646 |
| ii) | Interactive tasks, with or without new media like tablets | Ensure Vertical illumination, Minimum Glare, |
| iii) | Flexible table arrangement | Achieve good uniformity, Low contrast |
| iv) | Presentations held by the students | Good color rendering, daylight integration with intelligent sensors |
| v) | Equal learning environment at each time of the day and year | Intelligent Lighting management system with tunability and central control |
| vi) | Group and individual work | Intelligent Lighting management system with tunability and user interface |

## 8.3 Home

The human body has a natural circadian rhythm influenced by natural daylight. Artificial lighting can also affect this rhythm and impact overall well-being. Dynamic lighting solutions that mimic natural daylight can positively influence the sleep-wake cycle and enhance well-being. Smart lighting technology allows for customizable lighting scenarios based on individual preferences, which is beneficial for people with different chronotypes.

In homes, the following design concepts can be considered:

a) Different lighting systems
b) Emphasizing / presenting the rooms
c) Performing various visual tasks