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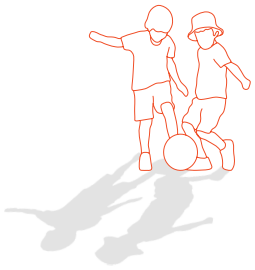

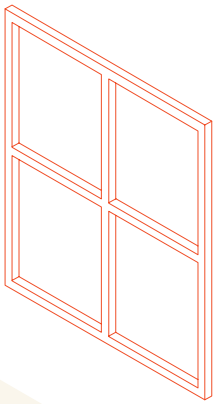

On Light

Learnings on light and how to implement Human Centric Lighting.

Text by Rachel Fay
Graphics by Liv Green

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On Light

with **corner**store

Text by Rachel Fay
Graphics by Liv Green

At Cornerstore, we take a research-based approach to design. Our research is focused on improving the human experience; creating physical environments that nurture better lifestyles; whether it be at home, at work or at play. Equally, we see design as an opportunity to make a meaningful contribution to the sustainability of our natural environment.

At the centre of our design philosophy are two core pillars: people and place.

Designing for people and place focuses on the relationship between people and their environment. Our guiding design ethos is a belief that the buildings we design should;

- Support human's in functioning well and encourage good health.
- As much as possible, should not damage or be harmful to the environment.

This report looks towards the future; investigating how we can better our practice and produce a healthier standard of Interior Design.

Afterall,

'We shape our buildings; thereafter they shape us'.
– Winston Churchill,1943

Chapter 1

A Healthier Standard of Design

Chapter 1.1

A human and environment centric approach

To design for true health and wellbeing it is critical to understand the biological needs of humans. It is the human body and the processes that comprise its function, that is *"the basis for any meaningful, health-related urban and building design."*[1]

A human-centric approach that recognizes humans as a part of nature, and not separate to, will naturally evolve into stewardship of the environment. *"A degraded habitat will produce degraded humans…if there is to be any true progress, then the entire life community must progress".*[2]

On average people spend 87% of their time in-doors[3]. We have a great responsibility as designers to create 'habitats' that support and nurture the health of humans living within a thriving ecosystem.

As the literature shows, lighting is one of the most important aspects in designing for health. However, the CIBSE Society of Light and Lighting highlights that, while knowledge and understanding is still evolving a robust standard that encompasses 'lighting for health' is yet to be developed.[4] Given the findings of the literature review there are several steps that we can implement within practice to produce a better design outcome that supports the health and wellbeing of occupants.

As designers we need to:

- Learn and understand the importance of natural light and the impact of light on the body.
- Learn and understand how light can harm biological function and reduce this impact in design.
- Recognise the importance of the colour of light and design accordingly.
- Design to minimise light pollution at night and reduce the need for artificial light.
- Design for variation – mimic the diversity experienced in nature in the design of healthy interiors.
- Do less – minimise the use of artificial lighting and subsequent consumption of energy.

"Light is not the problem, it's how we use it that's the problem".[5] Bogard advocates that *"too often our use of light at night is irresponsible and wasteful. What we really need is thoughtful and intelligent lighting that helps us to see at night, rather than simply blasting light everywhere."*[5] It is through thoughtful and intelligent design that interior environments can benefit from artificial light, without compromising on the experience of natural light and its benefits.

"Over the last three decades, scientific research has produced an increasing amount of knowledge on what human beings require for healthy living in both indoor and outdoor spaces. Taken together, this evidence constitutes a wake-up call to all those involved in the construction industry. Will it be possible to 'design' health into the places where we live, work and play? Can we, by doing so, create the living conditions for people to flourish around the clock and regardless of their age." [1]

- **The Velux Group.** *Sleep, Work, Live Report*, 2014.

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Why this should matter to you.

People thrive when they are in contact with nature. We are all aware of the benefits of our connection to nature, but it is not often capitalized upon. By designing to support the innate connection of humans and nature, there is an opportunity to increase our health and well-being and optimize our potential.

The Owner / Occupant

To ensure the longevity of our spaces they need to be well-loved by those who inhabit them. Occupying a space that nurtures your health and wellbeing will feel good. A tailored solution incorporating these principles of human and environment centric design will result in a space that caters to your needs, look good, nurtures your health and contributes to a healthier environment.

The employer

A space that nurtures the health and well-being of those within it will allow workers to function at their optimum and produce better performance outcomes - meaning better work, increased productivity and reduced sick leave.

The employee

Equally, working within an environment that is allowing you to be at your best will create higher work-satisfaction, whilst also contributing to a higher quality of wellbeing outside of work. An environment that supports good health and circadian synchronization during the day, will support you in getting a good night's sleep - crucial for restoration and repair.

The designer

With studies finding that on average people spend 87% of their time indoors, we have a great responsibility as designers to create 'habitats' that nurture human health and support a thriving ecosystem. It is imperative that as designers, we take an active role in researching and understanding the human species, our biology and the ecosystem in which we have evolved, to inform our design solutions.

Our society

A healthier society means a higher quality of life. Living better lifestyles, experiencing less illness, producing better work and having increased life-satisfaction will make for a better society. Taking this approach of 'prevention' to reduce ailments and avoiding the need for 'treatments', will reduce associated costs and produce better health outcomes.

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Chapter 2

Lighting in the environment

Chapter 2.1

How lighting presents in nature

We experience the world around us through light. It allows us to see and navigate our surrounding environments. It creates the rhythm in our lives; guiding the cycle of time through which we live our days. *"With the exception of high latitudes, life has evolved under bright days and dark nights"*.[1] We perceive light in nature from many sources: sunlight, moonlight, the glimmer of stars, the warmth of a fire and the glow of ocean phosphorescence. It is innate to our biology and our experience of place.

The way in which we encounter light dictates the 24-hour cycle of our days. Our experience of light is specific to place, it varies depending on latitude and weather and changes with the seasons. Throughout the cycle of the day the intensity of light and spectrum of colour changes. It is this variation in the natural experience of light which is so important to take note of and capture, in our interior spaces.

The energy of light - Wavelengths (nm)

The spectrum of light has a direct impact on the biological functions of our bodies. *"the skin and body respond to various wavelengths that affect a variety of biologic processes"*.[2] When thinking about how this applies in design, we need to consider the wavelength of light; where light sits on the energy spectrum, and the biological processes that will be triggered in response to interacting with light.

Light is energy. This energy is measured by its wavelength in units of nanometres (nm). The light we perceive in nature is mostly emitted by the sun. On the high end of this energy spectrum cosmic, gamma rays and x-rays are all absorbed by the atmosphere. Most of the UV radiation (200-320nm) is also absorbed, with only a small amount of UVB and UVA transmitting. The remaining energy that reaches the Earth's surface is the visible radiation and near-infrared radiation - what we perceive visually. This ranges from about 380nm in the deep violet and extends well into the near-infrared which begins at 780nm.[3] Within this spectrum, the colour of the light ranges from the high energy of violet, blue and green through to the lower energy of yellow, orange and red.

Light and Surface - Transmitted, Reflected, Refracted & Absorbed

Our perception of light depends on how light interacts with a surface. When it hits a surface, light will either be transmitted, reflected, refracted, or absorbed by a material. This will change the experience of light within a space depending on the materials and objects present.

The Electromagnetic Spectrum

Diagram of light's Electromagnetic Spectrum showing the different wavelengths of visible light (Lumenistics, 2014)

increase of energy — *increase in wavelength*

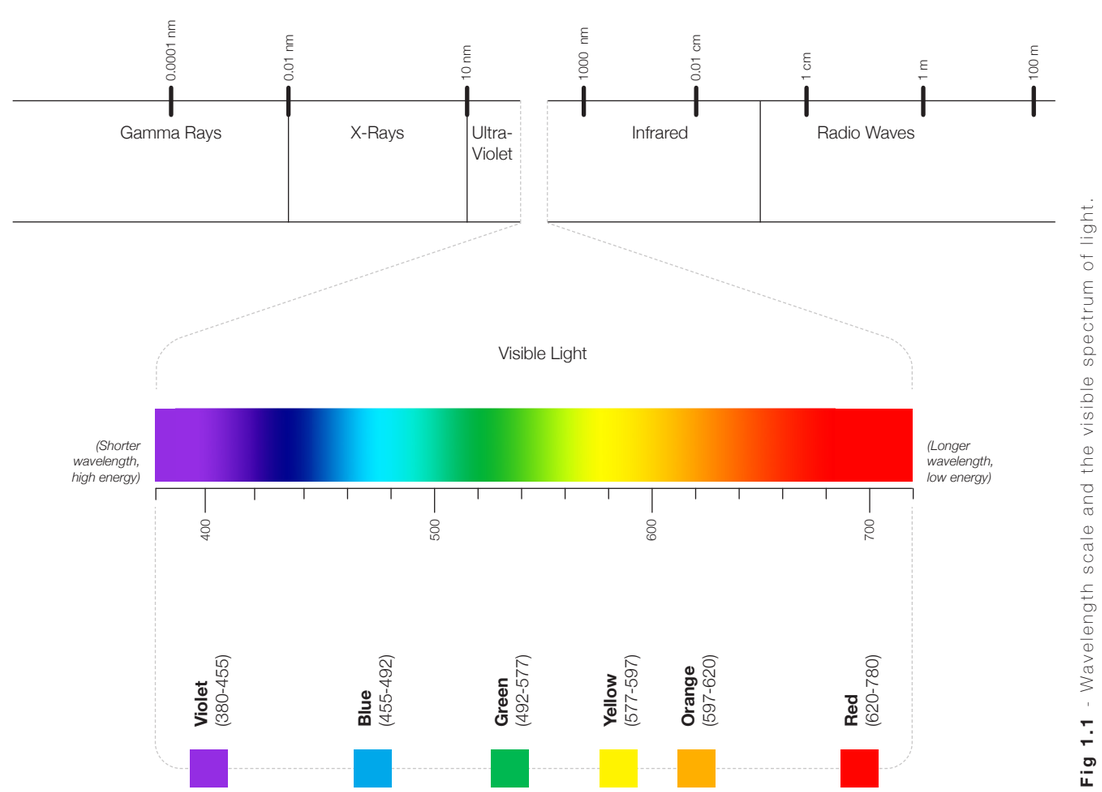
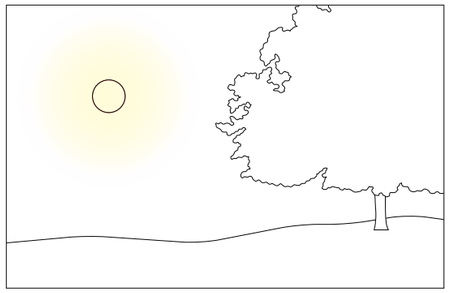


Fig 1.1 - Wavelength scale and the visible spectrum of light.

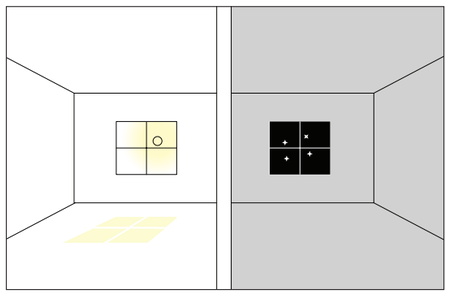
Key Learnings for Design

The first step in designing with light is to understand how light appears in nature and how best to harness it in interiors.



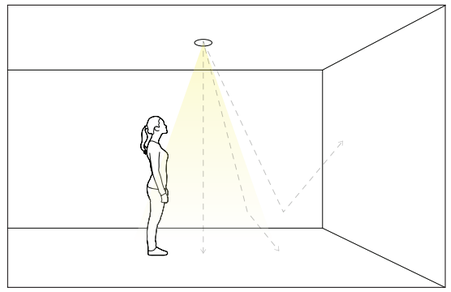
1. **The sun should be the first source of light.**

    - When thinking about lighting, be guided by how it appears in nature.



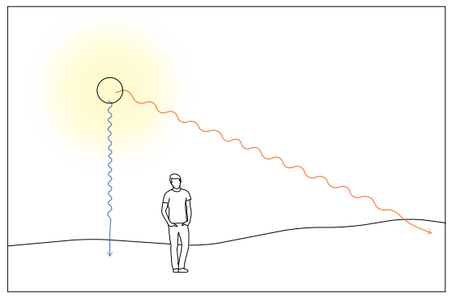
2. **Variation is key.**

    - Allow for the daylight of day and darkness of night.
    - Attune to the time of day and the season
    - Vary the spectrum and intensity of light throughout the day



3. **Our perception of light within a space will change depending on how light hits a surface.**

    - When it hits a surface, light will be transmitted, reflected, refracted or absorbed.



4. **There is an inverse relationship between wavelength and energy.**

    - The shorter the wavelength, the higher the energy.
    - The body responds to wavelengths which impact a variety of biological processes.
    - The visible spectrum of light is between 380nm – 1000nm and includes a colour spectrum from violet to red.

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Chapter 2.2

Human design and light

Charged by light: sunlight to energise, grow and heal

The human body has been designed to be energised, to grow and to heal through interaction with light. Sun exposure is the major source of Vitamin D for most humans [1]. Sunlight delivers the dose of UVB we require for Vitamin D synthesis[2] (between 290-315nm). Vitamin D is known to help the body absorb calcium which is essential for growth and good bone health, as well as having anti-inflammatory effects and strengthening the immune system. Low Vitamin D levels have been suggested to increase the risk of cancer, heart disease and hypertension, and are associated with obesity, depression, cognitive impairment and auto-immune diseases.[3]

Sunlight is also known to promote healing within the body. Light therapy - where patients are exposed to bright sunlight or artificial lights that have the same intensity in wavelength - has been successfully used to heal wounds and treat patients with depression.[4] Exposure to sunlight increases beta-endorphin levels which triggers a feeling of 'wellbeing'. This feeling has been demonstrated to improve mood, relieve pain and aid in relaxation.[1]

Whilst not enough exposure to sunlight can have damaging effects, too much exposure to UVB radiation has been associated with skin cancer, calling for sensible exposure to sunlight to maintain good health and well-being.[5]

Synchronization: Circadian rhythm and hormone regulation

Light is responsible for synchronising our internal body clock and regulating the function of our hormones. As daylight ebbs and flows our body responds to the rhythms of light in nature by producing the hormones which synchronize our body clock to the world around us. Our 'circadian rhythm' (derived from the Latin for about a day) is regulated by light. The most effective of regulators is blue light. When blue light (between 459-485nm) is absorbed by photo-receptors in the eye it triggers a decrease in the production of melatonin in our bodies - the hormone that helps us fall asleep. Bright, blue light which we experience around solar noon has an energising effect on the body and also increases cortisol levels - our stress hormone. On the other end of the spectrum, the softer red and near-infrared radiation of dawn and dusk help to activate our mitochondria and has a healing effect, encouraging wound healing and relieving pain.[6]

It is widely recognised that circadian entrainment is essential for health: light influences hormone secretion, heart rate, alertness, sleep, body temperature and gene expression. Medical studies stress the potential harm of circadian disruption. *"A growing body of evidence suggests that desynchronization of circadian rhythms may play a role in various tumoral diseases, diabetes, obesity, and depression."*[7] In 2007 the World Health Organisation (WHO) declared shift work at night a probable carcinogen finding higher rates of breast cancer, prostate cancer and cardiovascular disease amongst night-time shift workers.[7]

Exposure to sunlight at dawn and dusk are the most sensitive times for effective circadian entrainment.[8] The gradual change in colour and intensity of sunlight throughout the day further provides sensory stimulus to support healthy circadian functioning. Come nighttime the absence of light (particularly the stimulating effects of blue light) is crucial in preparing for deep and restful sleep and proper synchronisation.

Rest: The dark of night for restoration and repair

Chronobiology is *"the science of biological rhythms, more specifically the impact of the 24-hour light-dark cycle and seasonal changes in day length on biochemistry, physiology and behaviour in the living organism."*[9] Experiencing the light of day and absence of light at night is vital in supporting this synchronisation.

What is crucial to note from the study of chronobiology is that clock genes are an important factor in determining our circadian rhythmicity. Individuals vary greatly. This leads to differences in the timing of the sleep-wake cycle, otherwise known as 'chronotypes'. Genetically individuals will be wired to either be 'early' or 'late' wakers.[8] The World Health Design Journal report entitled *'Light Health and Wellbeing: Implications from chronobiology for architectural design'* found that *"In addition to a genetic determinant, chronotype changes with development".*[8] Therefore in designing for *true* health and well-being, it is important to cater to the chronotypes of those inhabiting the space as well as any develop-mental changes a space might need to nurture.

Our ecological binds: The impact of light pollution

Humans are not alone in this innate biological response to light. All organisms have evolved to have internal circadian rhythms that are in-tune with the cycles of day and night, or light and dark. Light pollution at night is not only disruptive to human sleep patterns but can also be harmful to animal species affecting their sleeping and migration patterns.[10]

Our biological design: An innate connection to nature

Despite the rapid advances of the modern industrial world human physiology and our biological needs remain tied to the processes of nature in which we have evolved. *"Genetically, we are essentially the same creatures we were at the beginning".*[10] Our surrounding environment and the spaces we inhabit must support and nurture these fundamental processes, if we want to maintain our health.

The rhythms of our body are in tune with the rhythms of the sun.

- **Esther M. Sternberg,** 2009.
Author, *Healing Spaces*

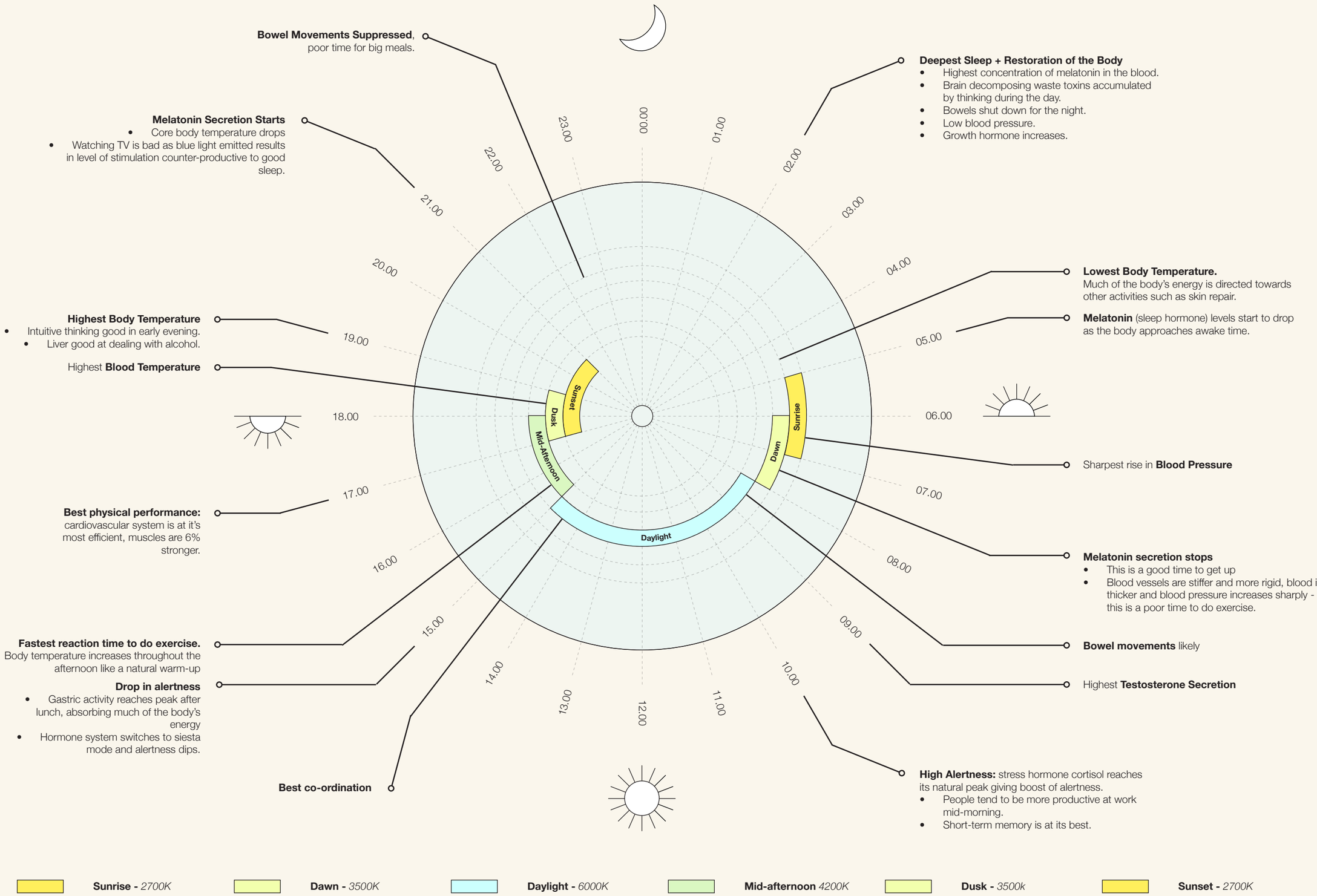
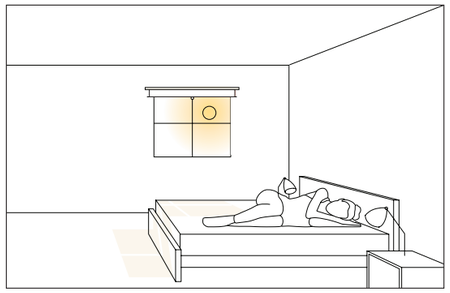


Fig 1.2 - How the human body responds to the rhythms of the sun.

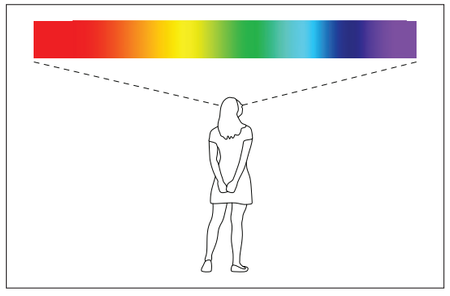
Key Learnings for Design

Our bodies have evolved to respond to light. The spaces we design should support and nurture our innate connection to light.



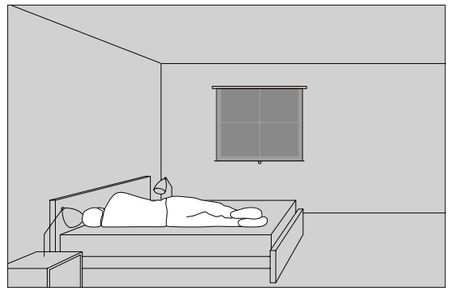
1. **Exposure to the red & near-infrared light of morning sun is key.**

   - Exposure to morning sun regulates circadian rhythms, supports optimal hormone function and has healing effects.
   - Reduce direct exposure of skin to shorter wavelengths, high energy blue sunlight experienced around Solar Noon.



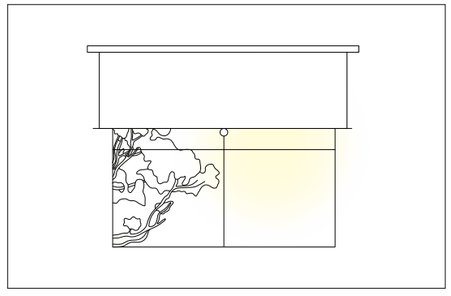
2. **Experience the full spectrum of light across the day.**

   - We need to be exposed to the full spectrum of light intensity and colour experienced across the day for sensory stimulus and well-being.



3. **Darkness of night.**

   - The absence of light at night is crucial in supporting healthy sleep patterns and hormone function.
   - Reduce use of light at night.
   - Minimise light pollution at night to reduce harm to other organism.



4. **In-sync with nature.**

   - Despite our industrial advances, our fundamental biological needs remain the same – humans need to be connected to the visual and sensory cues in nature that support circadian entrainment for good health.

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Chapter 2.3

The evolution of artificial light

Pre-19th century
Fire - A tool for survival

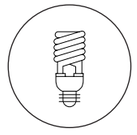
Since the origins of mankind, daylight from the sun has been the main source of light. The stone age saw humans develop ways of harnessing the flame as a tool for providing light. From then onwards until the 18th-century lighting was limited to sunlight and the flame.[1] Spaces were navigated and inhabited using these sources of light and architecture was designed to best capture and control the light available.

To harness daylight the design strategy would be specific to location, with the latitude and climate dictating the availability and quality of light. We still know it today as passive solar design - buildings designed to make the most of the sunlight. By designing for optimal orientation and allocating rooms according to function, we align the rhythms of our day to the path of the sun.

Utilising fire meant separating the flame from its source with burning branches becoming a tool for seeing. This became the first adaption of human-controlled light, what we now call ‘artificial light’. From here the flame developed into the oil lamp and candle and saw many evolutions in design. Whilst these were great tools for navigation of night, the light emitted was minimal and provided limited luminance to interiors.

19th century
Thermal lights – Incandescent & halogen bulbs

The next development in artificial lighting was gas lighting, which was pioneered in the early 18th century. Gas lamps emitted a wider spread of light with more intensity and were first used for street lighting before being integrated into public buildings and domestic environments. Efforts to create a more efficient gas lighting resulted in incandescent lighting followed by halogen bulbs. These thermal sources of light, like fire, emitted the longer-wavelength red and near-infrared light as seen in sunlight at dusk and dawn.



20th century
Non-thermal lights - Fluorescent lighting and LED

Electrical light sources took over as the most efficient form of lighting at the start of the 20th century,. By the 1950s, the fluorescent lamp, which provided a larger linear surface of light, became widely used for illuminating indoor commercial and office environments.[2] These fluorescents lamps emitted shorter wavelength radiation, similar to that of UV radiation at noon. They were also popular for their ability to conduct good colour rendering. Further developments were made to create a compact fluorescent lamp (CFL) which was more energy-efficient than incandescent lamps.

The 1960s saw advances in optics technology which led to the development of the highly energy-efficient light-emitting diodes or LEDs.[2] Like fluorescents, LEDs are stripped of the heat of infrared to make them more energy-efficient therefore emitting short-wavelength radiation within the blue spectrum of light.

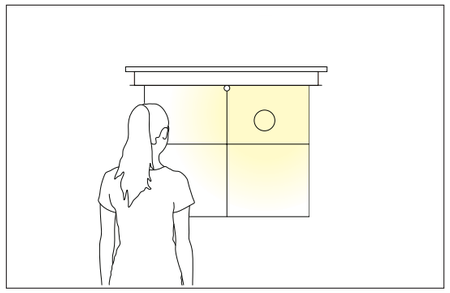
21st century
Towards a sustainable solution

Energy-efficiency has become the main priority for lighting applications in the 21st century with LEDs becoming the most prominent artificial light source seen in interiors today. As of 2009, the Australian Government began phasing out incandescent and halogen light bulbs in favour of energy-efficient LEDs and CFLs.

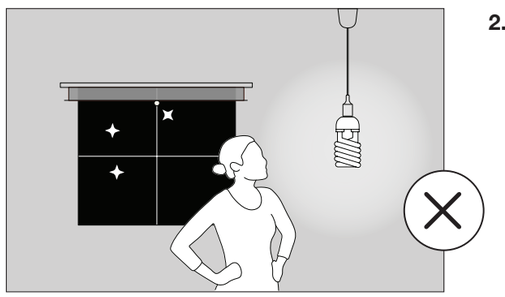
Increased energy efficiency has great environmental impact. However the widespread application and use of these short-wavelength light sources could be harmful to human health. The human body responds and interacts with the light it is exposed to. This needs to be carefully considered, with efforts made to both reduce the risk and increase the positive health effects of lighting within interiors.

Key Learnings for Design

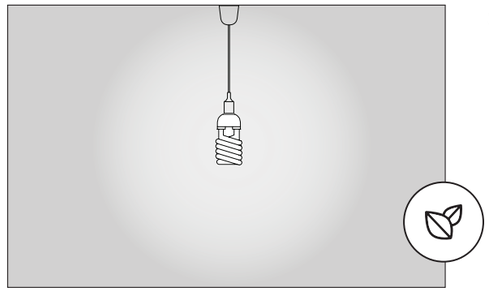
Innovations in lighting have shaped our lifestyles and the way we use our spaces, with the focus now on energy-efficient ways of living.



1. **For optimal health –** Sunlight, followed by red light and near-infrared light are the most beneficial source of light.



2. **Nighttime use of CFLs and LEDs that emit light in the blue spectrum is harmful to human health.**
   - The less heat required to light the source – the more short-wavelength blue-light radiation present.



3. **CFLs and LEDs are the most energy-efficient source of lighting.**
   - The less heat required to light the source – the more energy efficient.

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References

1. Ganslandt, Rudiger & Hofmann, Harald, 1992, *Handbook of Lighting Design.* Erco Vieweg publishing Company, Germany
2. Sliney, DH 2016, *'What is light? The visible spectrum and beyond.'* Eye (Lond), 30, 222–229, accessed 07 April 2020 <https://www.ncbi.nlm.nih.gov/pubmed/26768917>

Chapter 2.4

Lighting within the built environment

Pre-19th century: Daylight Architecture

Throughout the history of mankind, societies built their habitable spaces in response to the movement of the sun and the local climate in which they lived. 'Daylight architecture'[1] was driven by function and ambiance - capturing the instance of sunlight and controlling its intensity. This resulted in spaces that were both rational and beautiful, such as places of worship where carefully placed openings and celestial arched ceilings would capture the suns movement.

19th century: Daylight and healing

Scientific developments of the 19th century saw sunlight in architecture become a tool in the prevention and treatment of disease, before the discovery of antibiotics. Studies found that sunlight boosts resistance to infection and could kill a range of bacteria, which could make sunlight particularly useful for surface sterilisation.[2] One of the champions of this change was Florence Nightingale, a nurse in the Crimean War of 1854-1856. Nightingale insisted on letting sunlight and fresh air into the wards where patients were sick along with cleaning and sterilising cloths and preparing nourishing foods.[3] The result – a dramatic decline in hospital deaths and the reform of an architecture for healing.

20th century: Industrialisation - Productivity and efficiency

The industrial revolution saw a shift away from naturally lit interiors with the widespread application of artificial lighting. These developments in technology meant buildings no longer had to rely purely on windows for light – resulting in bigger floor plates that could accommodate more people. Further to this, artificial light at night provided the opportunity to do away with darkness altogether[1] resulting in an architecture that disconnected inhabitants from the cues they required from the outdoor world.

'Quantitative' lighting:

Defined by Rudiger Ganslandt and Harald Hofmann in the *'Handbook of Lighting Design'*, quantitative lighting was the first theoretical approach for designing with light - applying light as a tool for perception. Concerned with the physiological process of 'seeing', the result was a uniform application of ambient light to *"meet the requirements of the most difficult visual task to be performed in the given space"* whilst also adhering to standards for *"glare limitation and colour distortion"*.[1] This approach, however, lacked consideration for the psychological impacts that perception has such as the need to feel comfortable and safe.

'Qualitative' lighting:

Developments in lighting design focused on the psychology of perception and took inspiration from stage design to create a hierarchy for the application of lighting. Richard Kelly pioneered this new approach focusing on the *quality* of light, instead of a uniform *quantity*. Kelly highlighted three basic functions: ambient light, focal glow and play of brilliance.[1] This hierarchal application of lighting remains the prevailing strategy for lighting interiors today, defined by the following categories:

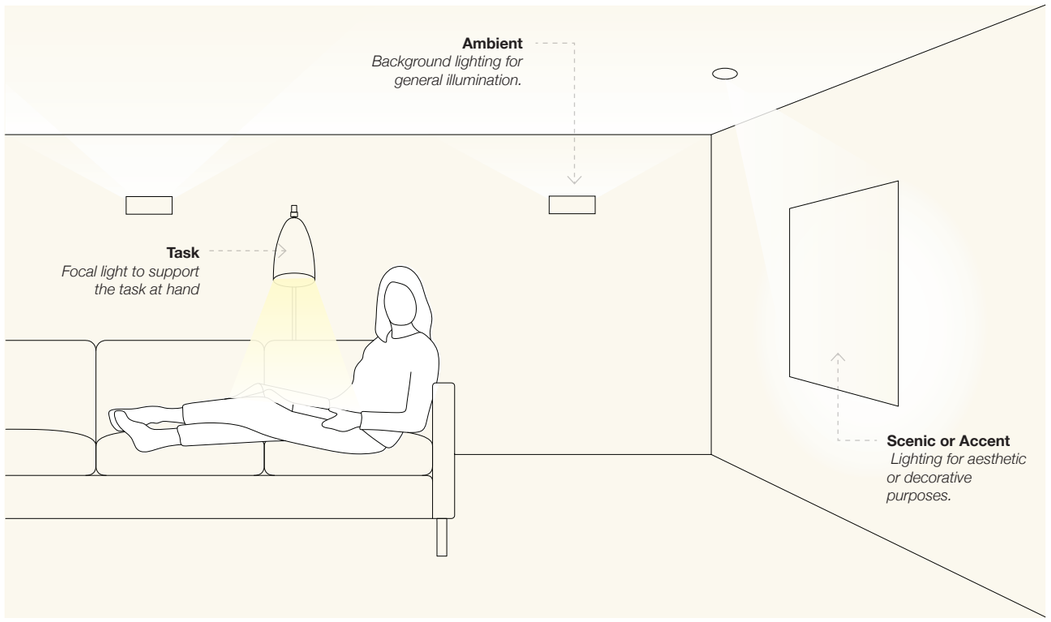


Fig 1.3 - The three basic types of lighting.

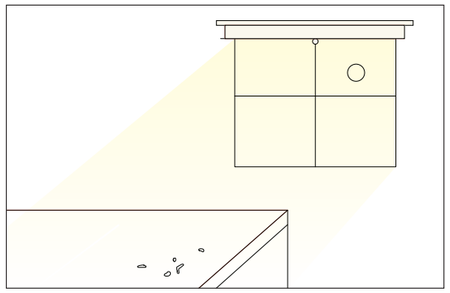
- **Ambient light:** 'Background' lighting for general illumination or 'ambience'
- **Task lighting:** Focal light to support the task at hand
- **Scenic or accent lighting:** For aesthetic or decorative purposes

21st century
Environment focused solutions

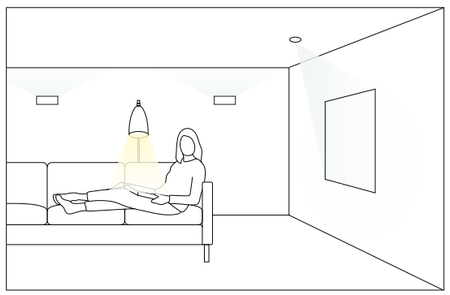
Today, the environment and sustainability are at the forefront of design thinking. What is neglected is the widespread application of an industry approach to lighting that is human and nature-centric - good for people and good for the environment. *"Architectural lighting must be redesigned to account for its biological and behavioural impact on humans".*[4] Optimising lighting and reconnecting our interior spaces with the rhythms of the outdoor world will improve health for inhabitants, save energy and create better learning and performance outcomes.[4]

Key Learnings for Design

A progressive lighting solution will be both energy efficient and human-centric.

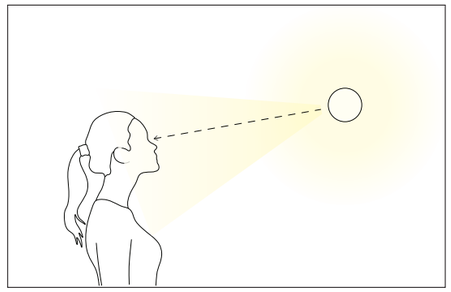


1. **Sunlight has anti-microbial properties and can be used in the prevention and treatment of disease.**

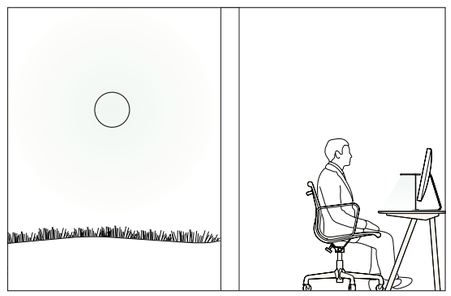


2. **Apply a hierarchy of lighting.**

   - Ambient Lighting
   - Task Lighting
   - Scenic or Accent Lighting



3. **Design to account for the biological and behavioural impact on humans.**



4. **Take a human and environment centric approach to lighting.**

   - Optimise lighting to connect with the rhythms of the outdoor world.

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Chapter 3

Implementing Human Centric Lighting.

Chapter 3.1

Human Centric Lighting (HCL)

Up until recently, lighting design has been focused on visual impact and energy efficiency. However, Human Centric Lighting (HCL) is fast-becoming the leading approach to light design in the 21st century. With growing recognition of the biological effects of light and the widespread application of LED technology, HCL is the next step in 'health'-focused lighting and LED design.[1]

Andy Taylor, Technical Manager at Light Culture, provides a detailed explanation of the parameters of HCL in his article, *'A Human-Centric lighting vision'*[1], published in the inaugural 2020 edition of Australian publication, Universal light. In summary, the key parameters of HCL are outlined in the following:

The metrics

The HCL method considers both the visual and non-visual effects of lighting and how these impact on biological function. There are two key metrics that are used to calculate the light from a luminaire and characterize it's circadian impact:

- **Equivalent Melanopic Lux (EML)** metric - developed at Manchester University and incorporated into the WELL Standard
- **Circadian Stimulus (CS)** value - as proposed by the Lighting Research Centre at Rensselaer Polytechnic

Using comprehensive data from the Spectral Power Distribution curve (SPD), both metrics can be used to define the level of stimulus from the luminaire that will effect the secretion of Melatonin (sleep hormone).

As a guiding principe -

High suppression is good for the beginning of the day, low suppression is good for nighttime.

However, there is debate amongst the industry as to which metric is the most appropriate and accurate method to use with concern that a more complex holistic analysis is needed.

A holistic HCL approach

Taylor stresses that *"the spectrum of light is not the only factor"* and to have a truly effective HCL solution we must also *"consider the amount of light, the distribution, timing and duration".*

Australian Standards

A factor that will impact the implementation of a HCL approach are The Australian Standards for lighting set out within the National Construction Code (NCC). The current standards are focused on power use and energy efficiency, making it difficult to successfully achieve the higher levels of illumination required of artificial lights to supplement the levels of illumination that would be experienced in daylight.

Given these parameters, it important to harness daylight in an effort to reduce energy consumption and achieve the levels of illuminance required. The future of HCL needs to be a human and environment-centric approach that effectively balances quality daylight and electric light to meet biological and visual requirements, while maintaining energy efficiency.

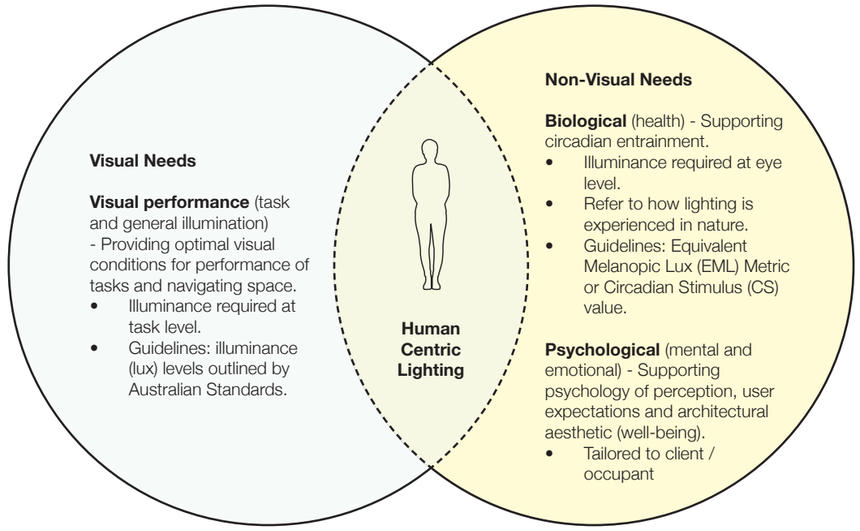

Fig 1.4 - Factors contributing to HCL.

Guidelines for HCL

As a starting point, a series of draft guidelines for the design of lighting within interior spaces were outlined within the World Health Design Journal 2010 report entitled *'Light Health and Wellbeing: Implications from chronobiology for architectural design'*[2]. Based on our literature review and the guidelines identified in this document, as well as those contained with the Litche Wissen 2018 report, '*Guide to Human Centric Lighting'*[3] and The Velux Group, 2014 Report, '*Sleep, Work, Live; Healthy living around the clock'*;[4] we have put together a series of guiding principles and strategies that can be used to assist in the design process.

The following principles and strategies lay the foundation for a tailored design solution that responds to people and place. There is not a 'one size fits all' approach that can be applied - the visual and biological requirements of inhabitants will vary depending on their needs, whilst the location will prescribe seasonal and weather variations.

Principles

The following principles form the foundation for a Human Centric Lighting approach that can be integrated into a tailored design solution.

1. **Know the occupant - Design to support their chronotype and visual requirements**

   - Elderly need more light for performance of visual tasks than younger people.
   - Adolescents have a delayed biological clock and would benefit from bright light first thing in the morning.

2. **Identify the location where light is required**

   - For biological impact: vertical illumination at eye level (approx. 1.2m)
   - For visual impact: horizontal illumination at the task level

3. **Prioritise daylight and passive design**

   - Design internal spaces to connect with the entrainment cues offered by the outdoor environment.
   - Artificial lighting is less effective than natural lighting for health and wellbeing as it lacks the variation in the quality and spectrum of light.
   - Aim to effectively synchronize natural light conditions with corresponding activities that take place on a regular basis throughout the day such as food preparation, different kinds of work and leisure activities.
   - Design to fully experience the daily and seasonal changes of the natural environment.
   - Design to encourage people to go outside regularly.

4. **Design for variation**

   - Allow for a higher intensity of light at certain times of the day, near the eye of the individual, without compromising visual comfort – as much as possible, this should be achieved through the use of daylight.
   - Vary the application and distribution of lighting.
   - Apply a hierarchy of light: Ambient, Task and Accent lighting.

5. **Design artificial lighting to simulate the characteristics of natural light**

   - Use when conditions are insufficient for daylight penetration.
   - Ensure the CCT is appropriate for the time of day and functions required.
   - Use sensors and responsive lighting systems to control lighting conditions.
   - Minimise light pollution at night – ensure the design and placement of lighting will allow adequate darkness.
   - Minimise use of artificial light where possible.

6. **Design to reduce negative effects of light**

   - Reduce glare, flicker and eye strain.
   - Shield exposure to harmful radiation.

7. **Allow for user control and adaptability**

   - Ensure that any window coverings / shades will still allow for daylight to be experienced – if a window has to be covered to reduce glare or ensure thermal comfort, ensure this does not completely block the internal connection to the outdoors and the entrainment cues needed for the circadian synchronisation.
   - Ensure the occupant knows how to best use and operate the space.
   - Consider an automated system to simulate daylight.

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Strategies

Consider applying the following stategies in the design resolution of your Human Centric Lighting.

1. **Use a combination of skylights and windows**

    - Distribute throughout walls for maximum light exposure.
    - Skylights are more effective for achieving the daylight illuminance levels at the eye required for circadian entrainment.

2. **Provide tunable fixtures and lighting controls** *Note: Particularly important for adolescents who have delayed body clock.*

    - Sunlight: window coverings, adjustable shades.
    - Artificial: separate switches, dimmable controls.

3. **Glazing**

    - Use glazing with minimal spectral filtering.
    - Select solar protective glazing and window films that do not change the spectral composition of light.

4. **Specification**

    - CRI 90+
    - Low energy - Reduce energy consumption and costs for home owners and operators.

5. **For each light source consider:**

    - Spectral Distribution
    - The amount of light
    - The distribution
    - Timing
    - Duration

6. **Reduce harmful effects of light through careful resolution in design**

    - Avoid disruptive direct light on people at night.
    - Carefully orient the field of view to light.
    - Shield exposed bulbs.
    - Avoid light pollution outside.
    - Avoid excessive lighting - often results when taking the overhead LED or halogen downlights approach.
    - Provide shading from harmful sunlight radiation and glare.

7. **Materiality**

    - Each surface in a room will reflect, absorb or transmit light.

8. **Avoiding glare from bright surfaces**

    - Bright surfaces should be as large as possible to be able to reflect sufficient light even without high luminance level.

9. **Provide an operating fact sheet for clients / users**

    - Outline the purpose and effects of lighting.
    - Explain how to best use and operate the space.

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2. Wirez-Justice, Anna, 2010, *'Light health and wellbeing: Implications from chronobiology for architectural design'*, World Health Design, pp.44-49, accessed 07 April 2020 < https://www.researchgate.net/publication/298215187_Light_Health_and_Wellbeing_Implications_from_chronobiology_for_architectural_design>
3. Schulz, Andreas, 2018, *'Guide to Human Centric Lighting'*. Licht.de, Accessed 6 May 2020 < http://en.licht.de/fileadmin/Publications/licht-wissen/1809_lw21_E_Guide_HCL_web.pdf>
4. The Velux Group, 2014 *'Sleep, Work, Live; Healthy living around the clock'*. Daylight and Architecture: Sleep, Work, Live, Vol.22, pp.35, accessed 13 April 2020 <https://issuu.com/da-magazine/docs/140925_da22_80p_for_ebook-no_spread>

Chapter 3.2

Harnessing natural light

1. Passive solar design

- Keep high angle summer sun out.
- Let low angle winter sun in.
- Provide shading for openings:
  - Deciduous trees are good for sun control.
  - Fixed shading above openings to block out high angle summer sun but let in low angle winter sun.
  - Provide adjustable shading (consider external and internal options).
- Provide windows at varying heights (standard and high) to allow for better air flow for ventilation.

2. Planning

- In general:
  - Bedrooms to the East to get morning sun.
  - Living face North to have maximum exposure to sunlight throughout day.
  - Utility and services to the south and west (depending on the direction of cooling breezes).
- Reduce exposed glazing to western façade – make sure there is shading.
- Design to encourage people to go outside at regular intervals: balconies, terraces, gardens.
- Allocate task areas close to windows (kitchen bench, workstations etc) .
- Higher ceilings allow for more light to fill a space.

3. Use a combination of skylights and windows

- Distribute windows throughout the walls in a room for maximum light exposure.
- Skylights are most effective for achieving the daylight illuminance levels at the eye required for circadian entrainment.
- Consider how light can be brought into the space through ceiling openings; atrium, light-shelf, light-well, voids.
- Consider how the light will react when it hits an internal surface – will it reflect, refract, transmit or be absorbed?
- Consider how you can redirect the lighting within the space to provide additional illumination.

4. Connection to outside

- Allow for views to outside – design internal spaces to connect with the entrainment cues offered by the outdoor environment.
- Design to fully experience the daily and seasonal changes of the natural environment.
- Design to encourage people to go outside regularly.

5. Glazing

- Use glazing with minimal spectral filtering.
- Select solar protective glazing and window films that do not change the spectral composition of light.

6. Allow for user adjustability and lighting control

- Provide window coverings and adjustable shades.

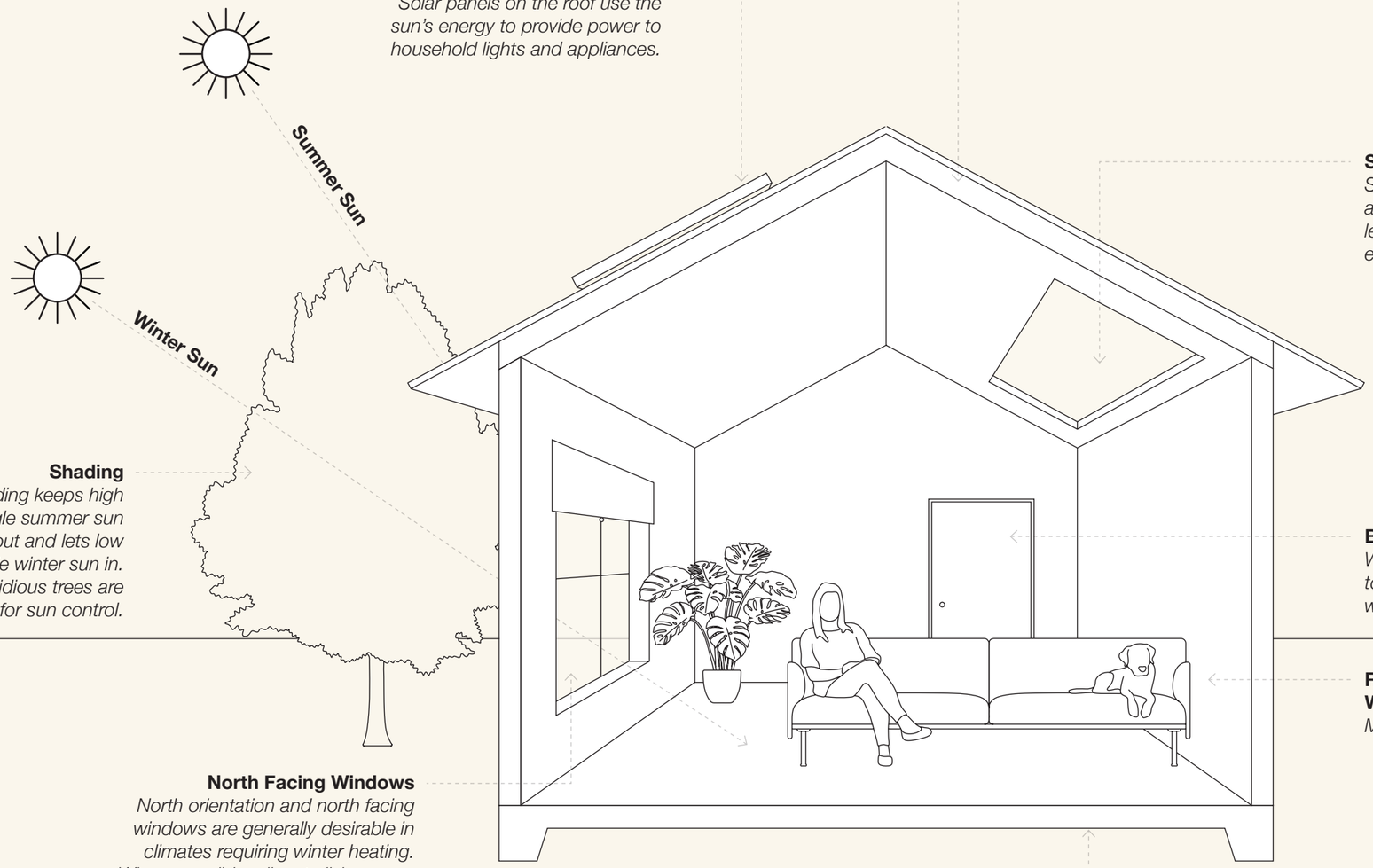
7. Avoid glare from bright surfaces

- Bright surfaces should be as large as possible to be able to reflect sufficient light even without high luminance levels.

Solar Panels
Solar panels on the roof use the sun's energy to provide power to household lights and appliances.

Insulated Walls and Roof
Insulate walls and roof to keep home warm in winter and cool in summer.

Skylight
Skylights are most effective for achieving the daylight illuminance levels required at the eye for effective circadian entrainment.



Shading
Shading keeps high angle summer sun out and lets low angle winter sun in. Decidious trees are good for sun control.

Bedroom to East
Where possible, provide bedrooms to the East with windows to wake with the morning sunlight.

Reduced exposed glazing to Western façade
Make sure there is shading.

North Facing Windows
North orientation and north facing windows are generally desirable in climates requiring winter heating. Where possible, allocate living areas to face north.

Thermal Mass Flooring
Thermal mass flooring captures solar energy during the day and re-radiates it at night, moderating internal temperatures.

Fig 1.5 - Passive solar design principles.

Chapter 3.3

Specifying artificial lighting

When specifying the colour of artificial lighting, there are two units of measurement to consider[1]:

- Correlated Colour Temperature (CCT)
- Colour Rendering Index (CRI).

Correlated Colour Temperature (CCT) – Measured by (K)

Measured on the Kelvin (K) temperature scale, the colour temperature describes the 'shade' of white light emitted

2700-3300K - Warm White
4500K - Neutral White
5300 – 6500K - Daylight

This scale, however, lacks complexity and does not provide any information as to the spectral output of the luminaire. Daylight is complex - it is made up of a combination of red and blue light (or short and long wavelength radiation) at any one time. Therefore this is difficult to mimic with artificial light. In daylight, blue light never appears without near-infrared or infra-red light.

Electric lighting peaks and troughs across the spectrum.[2] This is not represented on with the kelvin scale, meaning that while two light sources can be measured as the same Kelvin, their spectral composition can be different. One could theoretically have a greater proportion of blue (short-wavelength) light than the other.

In designing to support optimal circadian entrainment, it is important to refer to a spectral light chart for the chosen artificial luminaire to assess the level and distribution of blue light.

A rule of thumb

The following diagram can be used as a visual reference when thinking about how the wavelengths (nm) of the Solar Spectrum Scale compare to the Correlated Colour Temperature Scale (K) of artifical lighting.

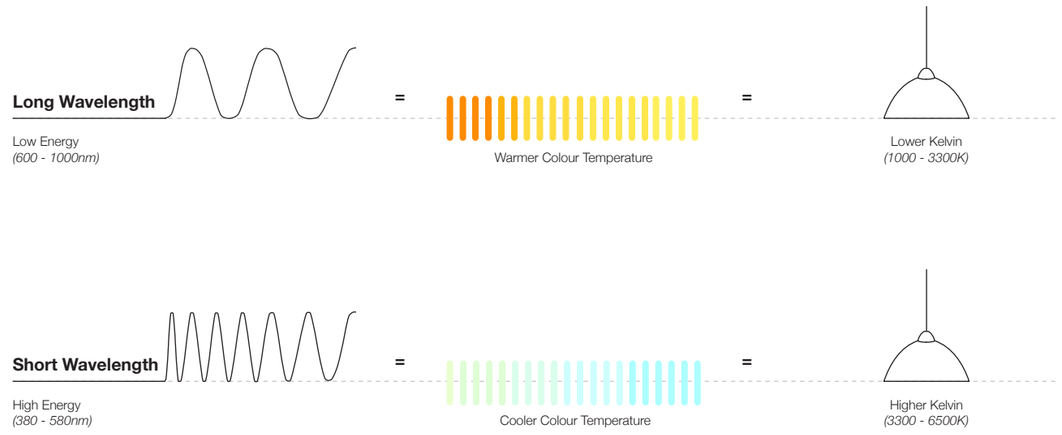


Fig 1.6 - Wavelengths and CCT.

Colour Temperature Chart

This chart shows the kelvin ratings and corresponding colour temperature of artifical light with reference to similar sources of natural light (Ref. Saving Light Bulbs, 2020)[4]

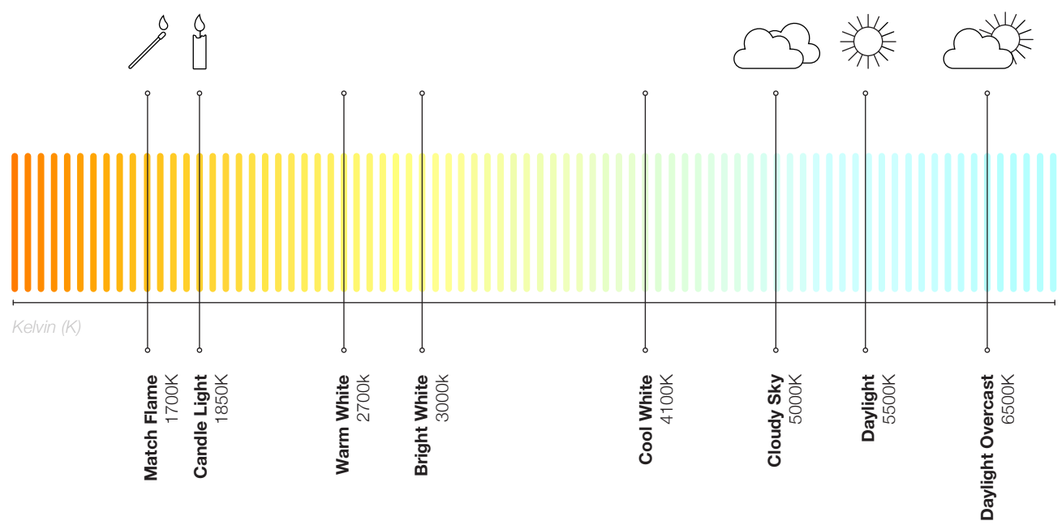


Fig 1.7 - Kelvin ratings and colour temperatures.

Colour Rendering Index (CRI)

A Colour Rendering Index measures how well a light source accurately represents the true colour of the objects in the space that is being illuminated. *'Your Home: Australia's guide to environmentally sustainable homes'*[1] presents the following outline:

Scale ranges from 0 – 100

0 Poor colour rendering
100 True to colour (e.g. sunlight)
65+ Reasonable
80+ Good
90+ Excellent

The Colour Rendering Index is a good way to measure the spectrum output of a light source in comparison to sunlight. Daylight has a CRI of 100 so aiming for 90 or above will achieve the best outcome.

Good colour rendering has been reported to support communication and sociability and improve the feelings of comfort and wellbeing. Aesthetically, rendering objects to appear as their true colour creates a better outcome. This applies to human skin where people appear more attractive and healthy with accurate colour rendering.[2]

Colour Rendering Chart

The Colour Rendering Index chart presents a visual comparison of each rating, showing how accurately a light source represents the true colour of an object. (Ref. Saving Light Bulbs, 2020)[4]

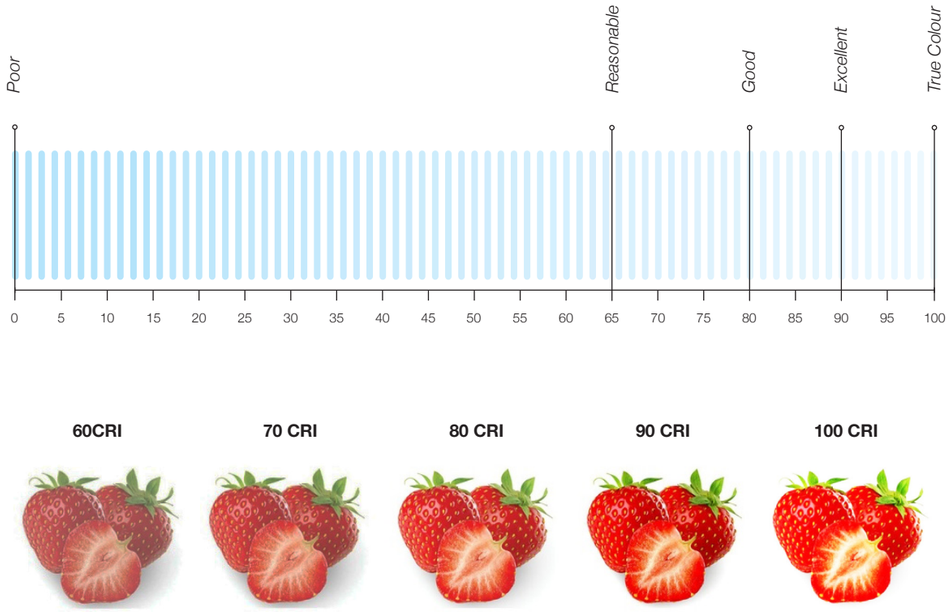


Fig 1.8 - A comparison of Colour Rendering Indices.

Other useful terminology for lighting specification

Luminous Flux – Measured by lumen (lm) – This measures the total amount of light emitted by a light source – or its brightness; the higher the lumens (lm) the brighter the lamp.

Lux (lx or lm-m2) – Lux measures the amount of light visible in an area and is equal to one lumen per square meter. This is an International System used for measuring the illumination of space and is governed by requirements set-out within the Australian Standards. The level of illuminance in which humans can perceive objects and their surroundings ranges from 100,000 lux, that being extremely bright sunlight, through to 0.01 lux of a moonlit night. Establishing the level of illumination (or lux) required will depend on the task at hand. It is important to provide a comfortable and safe visual environment to support the activities required.[2] In measuring this we need to address both the physical and psychological needs of occupants, to determine what level of perceptual information is required to create a sense of comfort and safety within our surrounding environment.

Watt (W) – Measures the electrical power a light source consumes.
Luminance – The amount of light (luminous flux) on a surface.
Illuminance – The total amount of light (luminous flux) falling on an area.

LUX Chart

The following chart shows typical illumination levels of both natural and artifical light sources along with a comparison of how these lux levels impact visual perception. (Ref. Stockman, A., & Sharpe, L. T. 2006)[5]

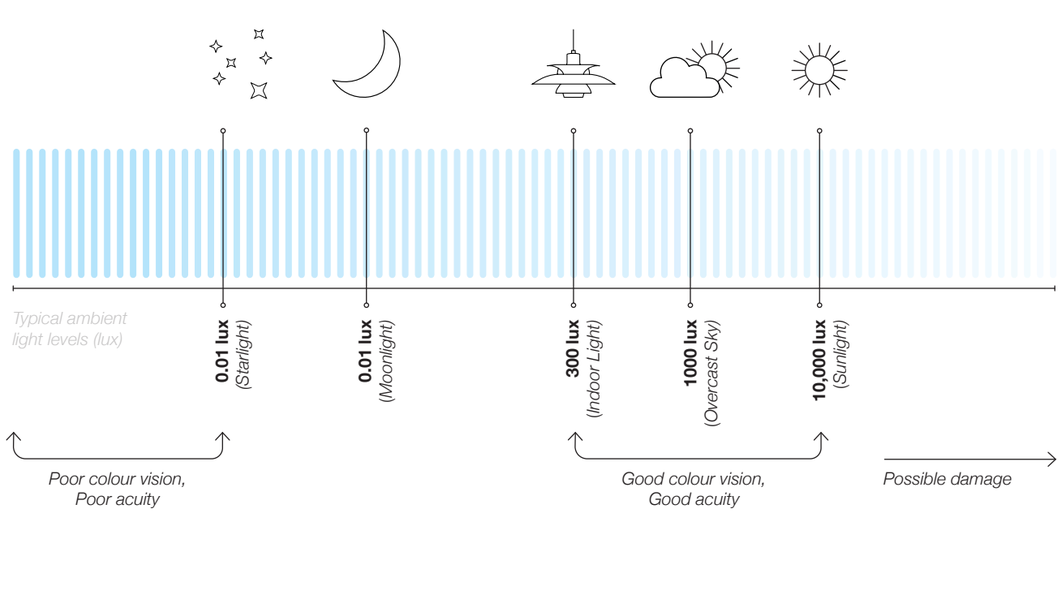


Fig 1.9 - Lux levels and visual performance.

Minimising the health risks associated with light exposure

Identify the potential health risks and which light sources are of concern to reduce the level of exposure to harm.

Health Concern	Applicable to the following light sources
UV emissions	**All lamps (particularly CFL and halogen - however LED emits little or no UV radiation)** • Sitting close to a compact fluorescent lamp (CFL) or halogen lamp, and being able to see the exposed light bulb means that some UV radiation will be received from the bulb • Provide a safe distance from the occupant to the light source – minimum 25cm away • Filter light - Shade lights to avoid direct UV and blue-light radiation from an exposed light source (Plastics are more absorbent than glass shades) • Reflect light - Reflect light on an interior surface to reduce UV levels – alcove or up-lighting is effective
Light sensitive conditions	**CFL** • Avoid use
Flicker	**Fluorescent + CFL** • Fluorescents with a noticeable flicker should be replaced • Maintain fluorescent lighting to minimise flicker
Exposure to light at night	**All artificial light sources - particularly Fluorescents, CFL + LED** • Reduce use of light at night • Particularly limit exposure to blue light at night
Glare	**Daylight & artificial light sources** • Avoid reflected glare from surfaces • Allow for adjustable blinds or shades to windows

(Ref. Enery Rating 2020)[5]

Comparing the Health, Environment and Economic impact of artificial light sources

When selecting which type of light source to use, compare and asses the pros and cons of each.

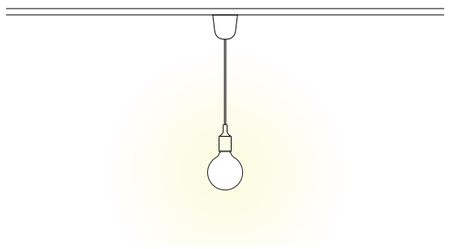
	Health	Environment	Economic
LED	- Emit a large amount blue-light (460-500nm) with little near-infrared. - Use at night could be harmful to human health.[3] - Choose warmer LED's at night (max.3000K)	+ Most energy-efficient light: emit the *most* light with the *least* heat	+ Cost the least to run and last the longest - More expensive to buy but becoming cheaper
Fluorescent + CFL	- Contain mercury which is a toxic heavy metal which is a hazard if the lamp is broken - Emit high AC electric and magnetic fields, UV radiation and radio-frequencies	+ More energy efficient than halogen and incandescent – generate a lot of light and not much heat - Not as efficient as LEDs and last half as long	+ Cost less to run than halogen and incandescent - Not as cheap to run as LED
Halogen	- Emit AC electric fields, AC magnetic fields and UV radiation	+ More energy-efficient than incandescent bulbs (uses less energy and lasts longer) - Nowhere near as efficient as CFL / LED	+ Cheapest light bulb to buy - Cost a lot to run and need to be replaced often
Incandescent *Phased out in Australia as of 2009*	+ 'Healthiest' form of artificial light - output of light is closest to that of daylight and fire + Offer good colour rendering	- Use a lot of electricity (waste 90% of energy transferring from heat) - Do not last long	- Cheap but will need to be replaced often (1x LED = 5 Incandescent bulbs)

(Ref. Enery Rating 2020)[6]

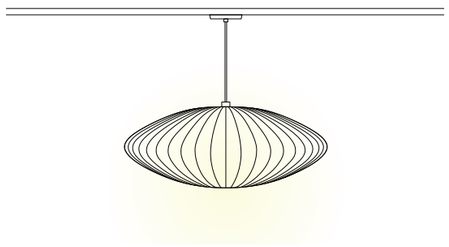
Types of Luminaires: What we mean by:

Exposed globe vs Shielded

Exposed – Bare globe allows light to be emitted from all angles.

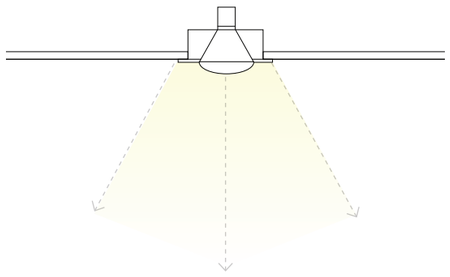


Shielded – A shade is provided, controlling the splay of light that is emitted from the globe.

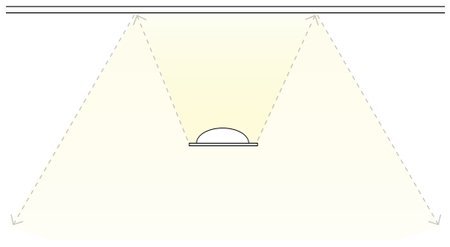


Direct vs Indirect

Direct – light emitted from a source that falls straight on an object, area or person.

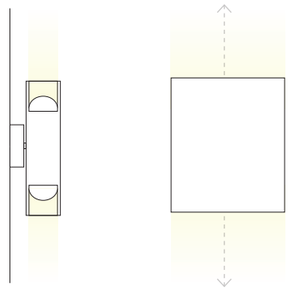


Indirect – any light that's not direct.



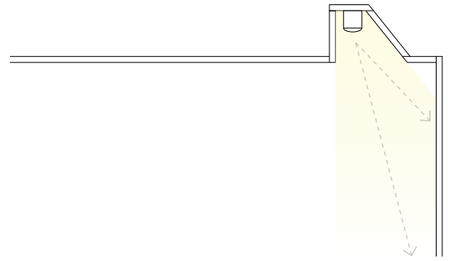
Types of Luminaires: Wall Mounted

Wall Sconce:



- 'Indirect' – light fitting fixed to wall
- Can have shielded or exposed globes
- Shielded lights emit light directed up or down the wall
- Good for ambient lighting

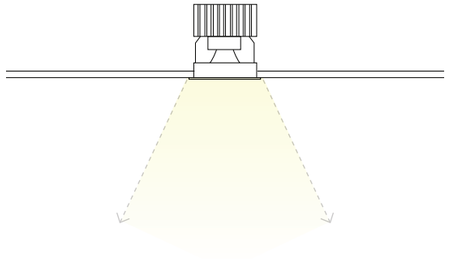
Wall Washer:



- 'Indirect' light - Provides a wash of lighting over the surface of a wall
- Often concealed within ceiling recess
- Good for ambient lighting

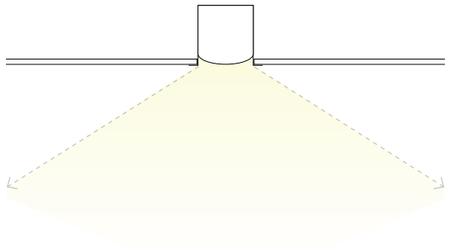
Types of Luminaires: Ceiling Mounted

Downlight



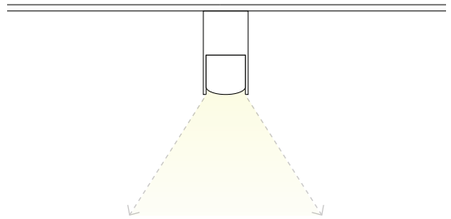
- ‘Direct’ – provide wide angle of light from ceiling to floor (typically downlights have a 180 degree beam spread)
- Most often recessed into ceiling - Can be surface mounted if seeking to avoid ceiling penetration for thermal sealing
- LED options widely available
- Provide general illumination / ambient lighting - Ineffective for task lighting and adding character to a space
- Best for daytime use. Avoid for night-time use - the wide, overhead spread of bright light disrupts the circadian rhythm
- Often over-used and excessively applied. Avoid plastering a ceiling with downlights – consider what purpose they are serving.

Recessed luminaires:



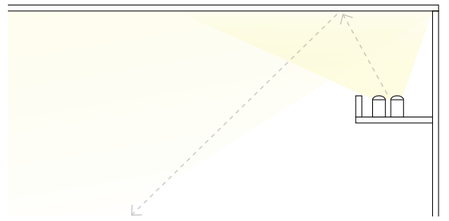
- ‘Direct’ - Light fitting is concealed within the ceiling to finish flush
- Commonly used in commercial and institutional spaces (fixtures can be sized to suit ceiling tile standard sizes)
- Often used for low ceilings or where uniform ceiling plane is desired
- Typically fluorescent fixtures however these are being superseded by LED fixtures which are more energy efficient and require less maintenance

Surface Mounted Luminaires:



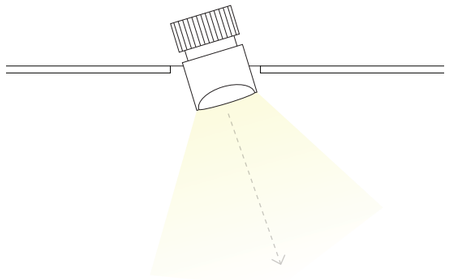
- ‘Direct’ – Light fittings that are fixed to the ceiling surface
- Often used to avoid ceiling penetration
- Provide general illumination / ambient lighting
- Ineffective for task lighting
- Best for daytime use only

Cove lighting:



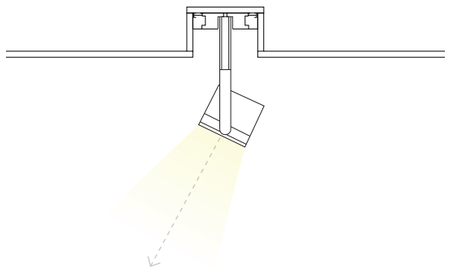
- ‘Indirect’ - Light fitting is concealed within a recess that allows the light to be directed towards the ceiling plane
- Can be incorporated into a wall or ceiling coffer
- Provides ambient lighting
- Ensure cove face and shield are tall enough to hide the light source

Spot light / Adjustable



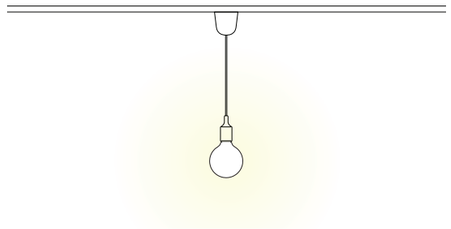
- ‘Direct’ – provides lighting directed onto an object or surface
- Good for scenic lighting
- Direction can be fixed or adjustable
- Best for day-time use or dimmed night time use and positioning to avoid circadian disruption

Track-mounted Luminaires



- ‘Direct’ – provides multiple light sources on a continuous track that can be directed onto an object or surface
- Good for scenic lighting
- Direction can be fixed or adjustable
- Best for day-time use or dimmed night time use and positioning to avoid circadian disruption

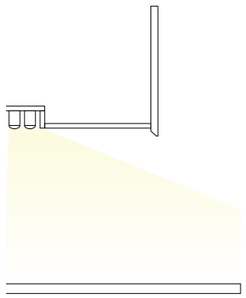
Pendant



- Can provide direct (down) or indirect (up) light
- Fixtures hang from the ceiling to provide lighting onto a surface
- Good for task and ambient lighting
- Daytime and night-time use
- Pendants used at night-time should have globe shielded
- Dimmed night time use and positioning to avoid circadian disruption

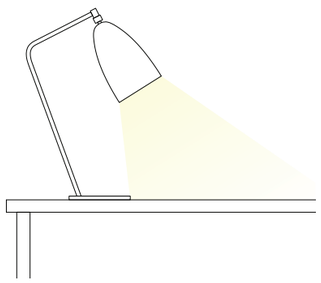
Types of Luminaires: Task Lighting

Under Cabinet / Shelf



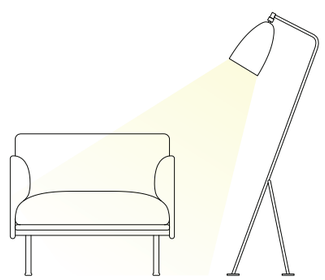
- ‘Direct’ light - Provides lighting to illuminate a surface area for task being conducted
- Can be down light or LED strip lighting
- Good for task lighting
- Good for use during the day and night

Table Lamp



- ‘Direct’ light - Provides lighting to illuminate a surface area for task being conducted
- Direction of lighting can be fixed or adjustable
- Good for task lighting
- Good for use during the day and night
- Avoid using CFL and halogen light bulb within open shade as pictured - may emit small amounts of UV radiation (or provide a safe distance between exposed light source and person - min 25cm away)

Floor Lamp



- ‘Direct’ light - Provides lighting to illuminate a surface area for task being conducted
- Direction of lighting can be fixed or adjustable
- Good for task lighting
- Good for use during the day and night
- Avoid using CFL and halogen light bulb within open shade as pictured - may emit small amounts of UV radiation (or provide a safe distance between exposed light source and person - min 25cm away)

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6. Energy Rating 2020, Commonwealth of Australia (E3 Program); Accessed 07 April 2020 *<https://www.energyrating.gov.au>*

Chapter 4

A Guide to Design

Chapter 4.1

Establish a lighting brief

The following summary can be used as a guide of how to implement these practices into the interior design process. This profile can be developed as part of a return brief, ensuring a holistic design response that considers lighting from the start of a project. To ensure the best outcome, this process should involve collaboration with lighting specialists and suppliers to resolve the design & specification.

Identify the aim:

- **People -** To support and enhance the health of inhabitants.
- **Place -** To connect with the surrounding environment and live in tune with nature.

Outline the design approach:

Prioritise daylight. Support with the sensitive application of artificial lighting that is integrated into a tailored design solution.

Project Profile

Identify the following information:

1. Who are the inhabitants? (Circadian system requirements).
   - Chronotype
   - Age / Developmental Stage
   - Genetic predisposition (late or early riser)

2. What are their needs? (Visual system requirements).
   - How they'll use / inhabit the space
   - General areas
   - Specific tasks and activities

3. When will the light be experienced?
   - Time of day and duration of exposure
   - Time of year: Seasonal variations

4. Where is the project / space located?
   - Latitude
   - Climate
   - Weather

5. How will light be experienced & applied
   - Natural / Artificial
   - Task / Ambient / Scenic

Biological System Requirements

Once the chronotypes are identified, refer to the *Body Clock Chart (Fig 1.2)* for guidance as to the level of light required at various times throughout the day for effective Circadian entrainment.

- Illuminance *(depends on time of day)*
- Location *(at eye level)*
- How often?
- Best way to achieve *(natural or artificial)*

Visual System Requirements

Once the tasks and activities are identified, refer to AS/NZS 1680.2.1:2008 Interior and Workplace Lighting for guidance on the minimum lighting levels required for specific tasks.

- Illuminance *(depends on the task)*
- Location *(at task level)*
- How often?
- Best way to achieve: *(natural or artificial)*

Type and Quality of Light

Once both the circadian system and visual system requirements are identified, establish a brief for the type and quality of light required in each space.

- Daylight levels – The spectrum, quality and duration of exposure to daylight. Spectrum measured in Wavelengths (nm)
- Distribution ¬ Where light is needed, how much, types of light sources
- Illuminance – The overall amount of light required (lx) for the function / task
- Luminance – The intensity of light required from light source (lm)
- Colour temperature – Kelvin (K)
- Colour Rendering Index (CRI)
- Materiality – Does it reflect, refract, absorb or transmit light?
- Controls – What controls are required (for natural and artificial) and where should they be located?
- Flicker & Glare – What factors need to be considered to reduce?

Morning | Noon | Evening | Night

06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00

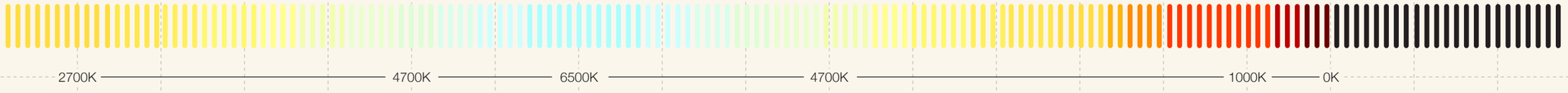
Biological

To design for our biological requirements we must harness daylight and design artificial lighting to simulate the characteristics of natural light.

For circadian entrainment, illuminance at eye level is most effective.

Natural Lighting

Artificial Lighting



2700K — 4700K — 6500K — 4700K — 1000K — 0K

When specifying artificial lighting ensure the CCT (K) is appropriate for the time of day in which the lamp will be used.

Identify lux levels required for effective entrainment & map location on floor plan.

Visual

To design for our visual requirements we need to provide adequate illuminanation to comfortably navigate the space and perform the tasks required.

General lighting provides 'background' illuminance for general navigation.

For task lighting, provide light at task level to adequately illuminate the object or surface.

General Lighting

Task Lighting

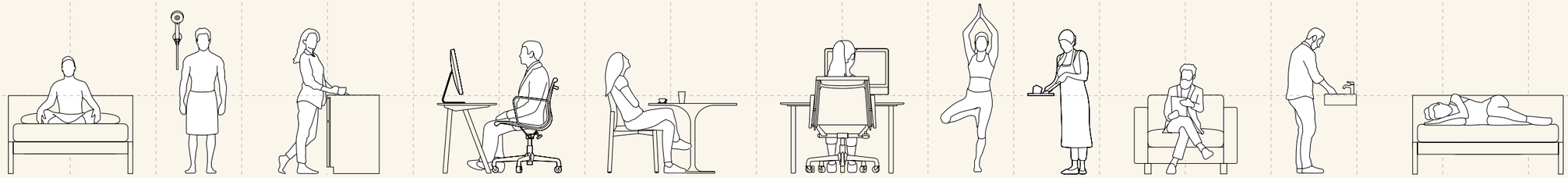
For general illuminance during the daytime, wherever possible we should prioritise and rely on natural light.

Identify lux levels required for visual performace & map location on floor plan.

As daylight decreases, indirect warm ambient lighting can be used to support visual perception.

In the evening, ambient lighting ideally should come from warm red light sources - such as fire and candlelight.

Provide complete darkness for restful sleep.



Wake | **Wash** | **Cook + Eat** | **Work** | **Eat** | **Work** | **Play** | **Cook / Eat** | **Unwind** | **Wash** | **Sleep**

Identify lux levels required as per Australian Standards & map location on floor plan.

Fig 2.1 - Mapping a day in the life of the occupant to design an HCL solution.

About a day

Designing with daylight and artificial light
to support circadian synchonisation

Sunrise

- Sunrise exposure is ideal – it is the most effective for circadian entrainment and has the healing qualities of near-infrared light.
- Illuminance levels between 300 to 500 lx at the eye with a light colour similar to daylight for a few hours in the morning are sufficient to synchronise circadian rhythm.
- Aim for light sources that have a high suppression of melatonin (minimum 200 Melanopic lux)*.

Daytime

- Keep illuminance levels between 300 and 500 lx on the eye throughout the entire work day.
- The lighting should be equal to daylight quality.
- Increasing blue light helps keep us alert.
- Use cooler CCT (Neutral white light / blue light) – at least 5500 K until the early afternoon.
- Provide activating lighting levels throughout the day.
- Illuminance levels between 1,000-2,000 lux should be encountered at a number of fixed 20min intervals throughout the day for effective entrainment whilst keeping energy consumption to a minimum.
- Alternatively, encourage people to go outside at regular intervals: balconies, terraces, gardens.
- Allow for dynamic light changes: Change the intensity and CCT throughout the day.
- Provide wide-area light.
- Vary the type and distribution of lighting throughout the space.

Sunset

- Use warmer CCT: 2,700K - 3,000K maximum (even for standard illuminance levels for performing visual tasks).
- Reduce blue light: it is stimulating and melatonin-suppressing.

Nighttime

- Periods of exposure to light should be short (if any).
- Use light sources that have a low suppression of melatonin (maximum 50 Melanopic lux).*
- Provide focused light – to illuminate tasks where required and support visual comfort.
- Shield light to avoid light pollution outside and stimulation at eye level.
- Transition to low illuminance levels on the eye two hours before going to bed.
- Avoid screens 2-3 hours before bed.
- Candle light is best in preparation for sleep.
- Ensure complete darkness for sleep.

**According to the WELL Building Standard.*
(To the extent allowable by Australian Standards).

Natural course of daylight and course of artificial light for designing an HCL solution

The following two graphs suggest a basic foundation to follow for an HCL solution. Here we show the natural course of daylight and how this could inform the artificial lighting approach.

Summertime Light Exposure

Graph based on AEST.
In the summer graph, the artificial course of daylight follows the rising and falling path of the natural course of daylight, with a suggested fluctuation of peaks of exposure to the brighter levels of light around midday. (Ref. Schulz, Andreas. 2018)[1]

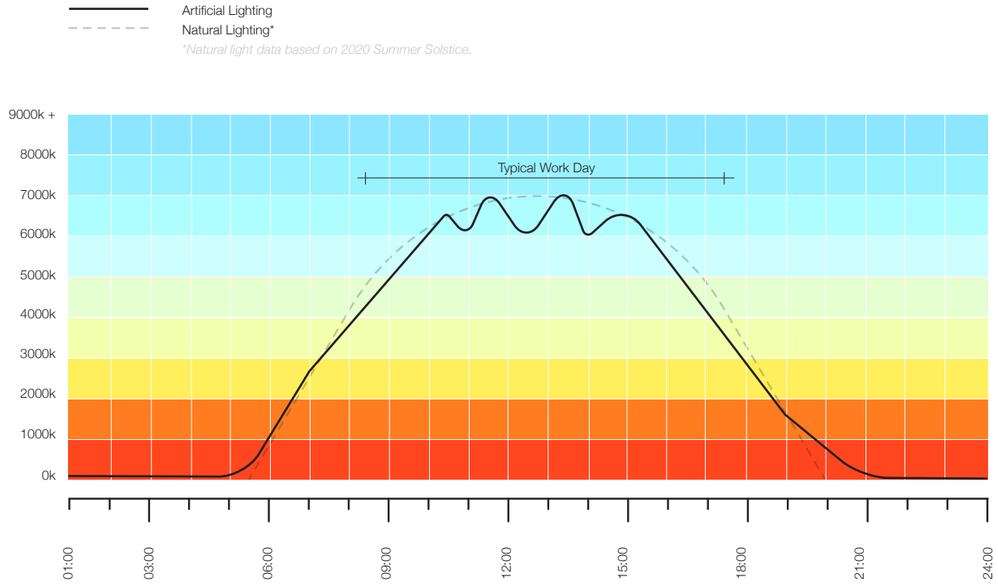


Fig 2.2 - AEST Summer light exposure for HCL.

Wintertime Light Exposure

Graph based on AEST.
In the winter graph, the artificial courseof daylight follows the rising path of the natural course of daylight, with a suggested fluctuation of peaks of exposure to the brighter levels of light around midday. However, the falling course of artificial daylight is extended to prolong the length of the day. This is to account for providing sufficient light for the tasks required to a reasonable extent - without adversely impacting health. (Ref. Schulz, Andreas. 2018)[1]

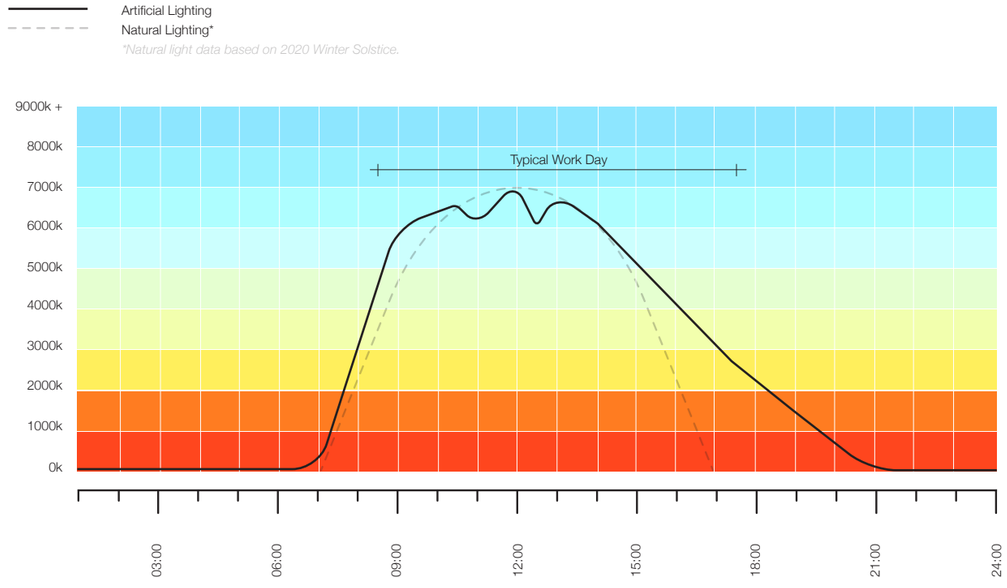


Fig 2.3 - AEST Winter light exposure for HCL.

Chapter 4.2

Light *At Home*

When designing lighting for the home the key consideration is allowing inhabitants to live attuned with nature. Inhabitants experience the rhythms of their external environment to support effective circadian entrainment throughout the day. Providing the option for individual user control and adaptability ensures the flexibility and longevity of the home as the occupant's age and change.

Requirements for the home:
- areas for rest and sleep
- areas to wash and clean
- areas to cook and eat
- areas for relaxation and activity

To design a successful HCL solution, we need to address the visual functions required within each room and the time of day in which these spaces will be used (to support optimal biological function).

The Licht.de, *'Guide to Human Centric Lighting (HCL)'* report presents four application case studies of how to implement HCL in design projects. Based on this report, we have summarised the key factors and strategies that can be implemented to produce an effective HCL home solution.

Identify the aim

- Create an environment that feels like 'home' (however the occupant defines 'home').
- Support the health and well-being of occupants.
- Allow the tasks required to be completed well and with ease.
- Allow for flexibility of function and use.
- Provide solutions that cater to each room.
- Provide the option for automation for different functions.

Identify the needs

- Performance of the visual tasks required.
- Spaces for rest, washing, nourishment, relaxation and be activites.
- Flexibility in how tasks are performed and how rooms can be used.
- Supporting ergonomics and health.
- Adjusting lighting to time of day and time of year.
- Adjusting lighting to the user's individual needs.
- Allow automated and manual control systems (for household and individual).

Strategies

- Smooth transition of light throughout the day and year corresponding to daylight.
- Direct light for performance of visual tasks at task level (allow for dimming after dark).
- Provide light on the face in mirror.
- Allow for separate lighting systems and dimming controls.
- Allow separate switches for lights and fan.
- Reduce blue spectrum of light after dark.

The following diagram identifies the Visual and Non-Visual requirements that contribute to an HCL solution for the home.

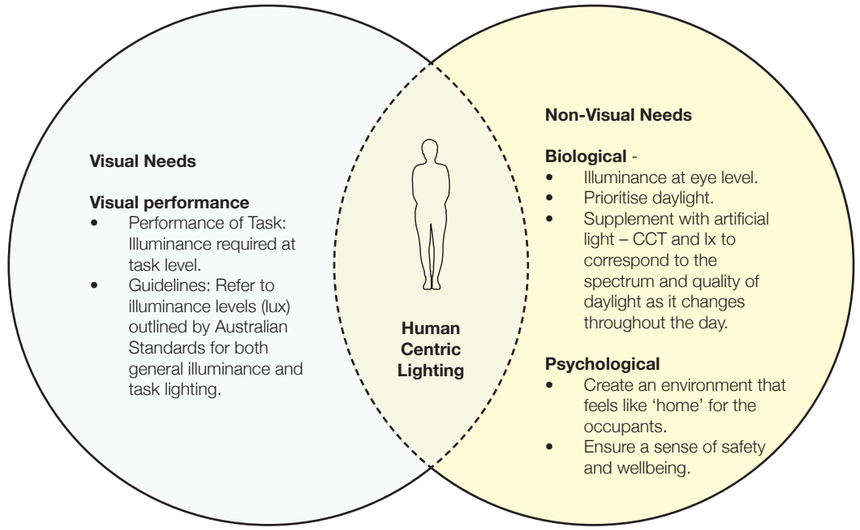


Fig 2.4 - Factors contributing to HCL At Home.

Light Exposure At Home

Graph based on AEST summertime.
The following graph suggests a basic foundation to follow for an HCL solution for the home. Here we show the natural course of daylight and how this could inform the artificial lighting for the home. (Ref. Schulz, Andreas. 2018)[1]

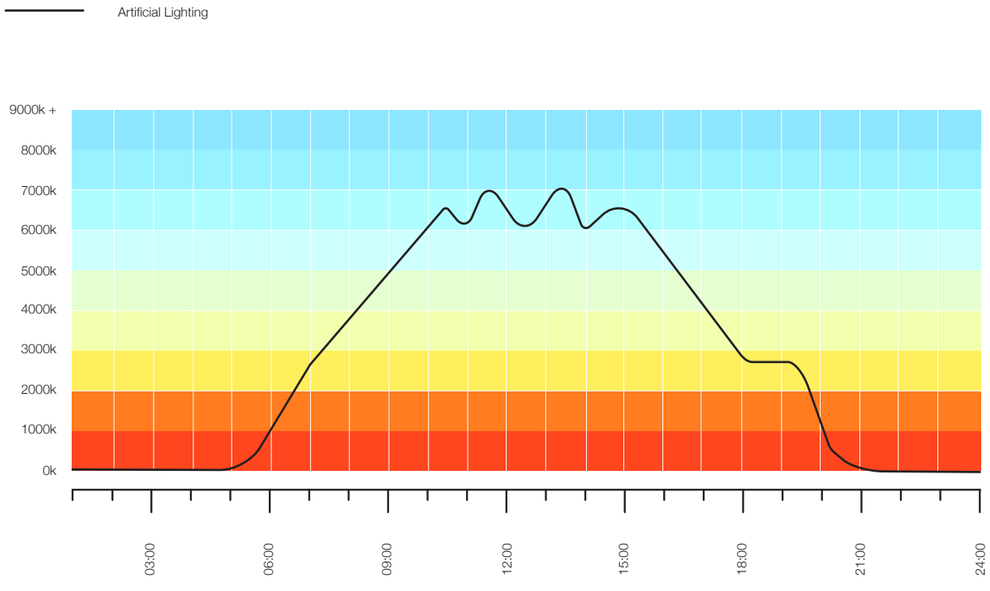
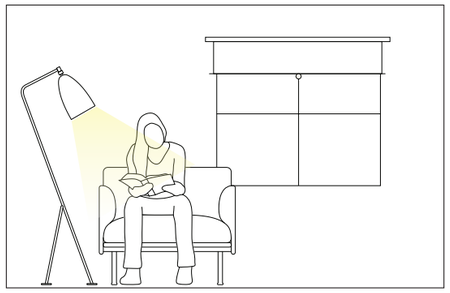


Fig 2.5 - AEST Summer light exposure for HCL At Home.

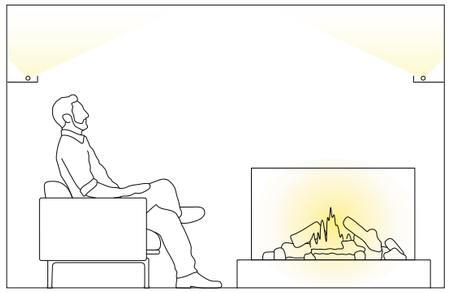
To light the home, a successful HCL approach will allow for each room to function in various settings, catering to the occupants and their daily routine. The following scenes are a series of suggestions of ways in which this could be achieved. Here we prioritise daylight during day and support with the sensitive application of artificial lighting that would be integrated into a tailored design solution.

At Home: Living

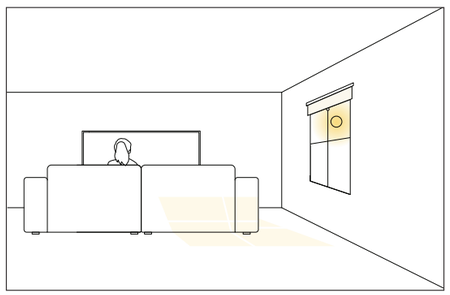
Reading
Provide warm, direct light onto the book or tablet. Avoid light in eyes. Consider dimmable control and adjustable positioning. For example, a shaded floor lamp.



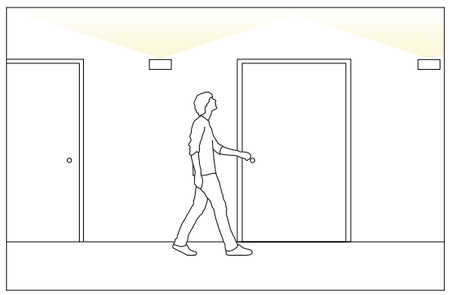
Ambient
Provide warm, indirect light. Avoid light in eyes. Allow for dimmable control. For example, wall or cove uplighting. A fireplace in cooler months can provide soothing light and warmth.



Watching TV
Avoid screens 2 hours before bed. Preferably no screens after dark OR apply blue light blocking filters. For example, use during-daylight hours.

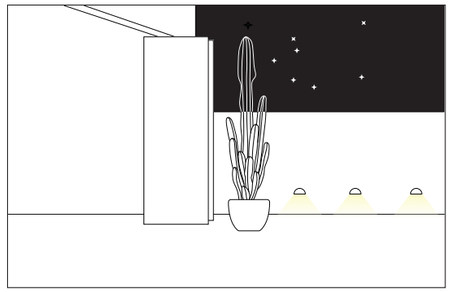


Corridors
Provide enough light to light the pathway. Consider tunable colour for day/night. Allow for dimmable control. For example, wall lighting with option for up / down lighting or both.

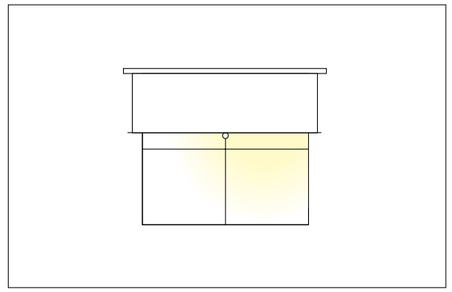


At Home: Outdoors

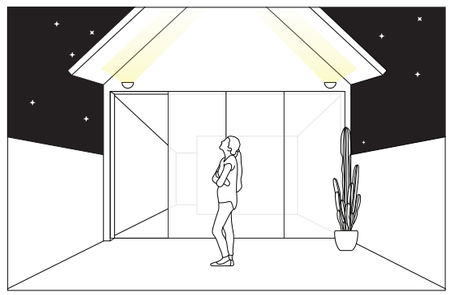
Pathways
Provide warm light, washing down with globe shielded to avoid light pollution (light going up into the night sky). For example, low shaded wall lights.



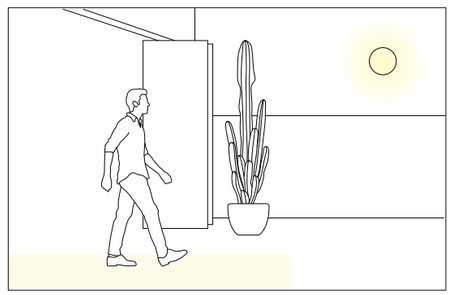
Sun Protection & Privacy
Provide operable window coverings and external shading. These can be automated / sensor or manually controlled. Consider varied levels of light transmission and prviacy.



Ambient
Provide warm, shaded light and dimmable control. For example, if providing up-lighting ensure it is shielded by a roof overhead to avoid light pollution.

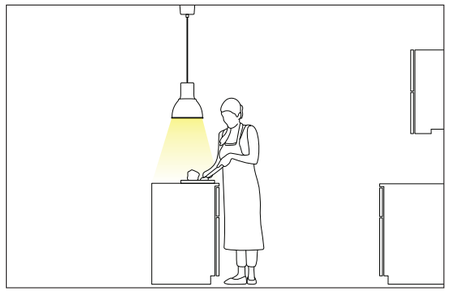


Step Outside
Design to encourage occupants to step outside regularly - For example, provide balconies, terraces and connections to outdoors.

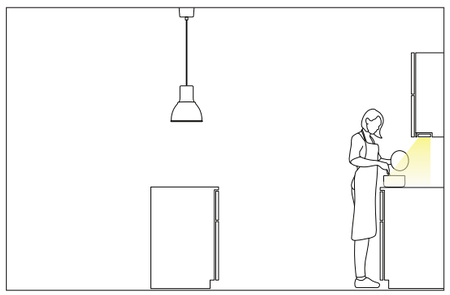


At Home: Kitchen

Cooking
Provide warm, direct light on the work surface. Avoid light in eyes. Consider dimmable control. For example, a shaded pendant lamp over island bench directing light downwards.

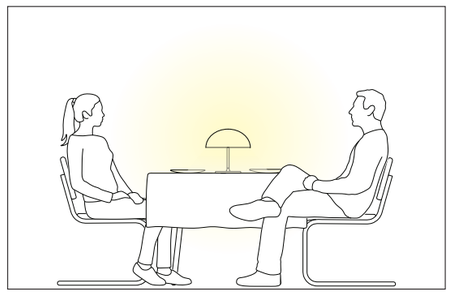


Cooking
Provide warm, direct light on the work surface. Avoid light in eyes. Consider dimmable control. For example, an LED downlight or strip lighting positioned under cabinets or shelving.

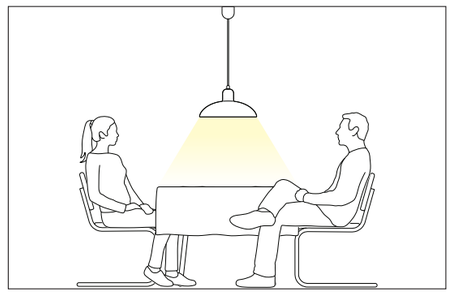


At Home: Dining

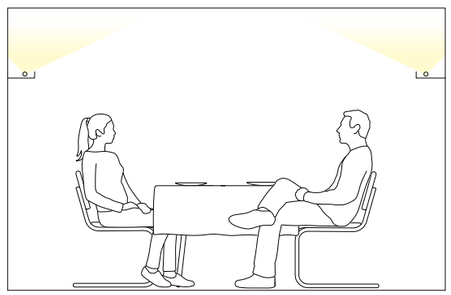
Dining
Provide warm, direct light on table surface. Avoid light in eyes. Consider dimmable control. For example, a translucent shaded table lamp emitting a soft glow.



Dining
Provide warm, direct light on table surface. Avoid light in eyes. Consider dimmable control. For example, shaded pendant lamp directing light down onto the table setting.

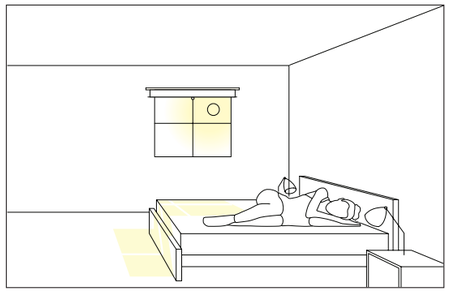


Dining
Provide warm, indirect ambient light. Avoid light in eyes. Consider dimmable control. For example, wall or recessed cove up lighting, provides illuminance for conversation & eating.

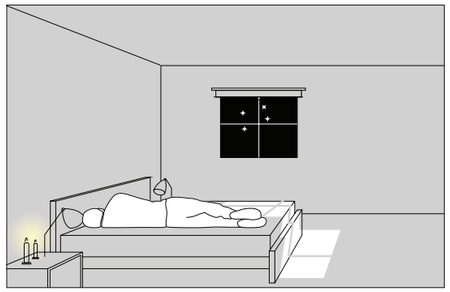


At Home: Bedroom

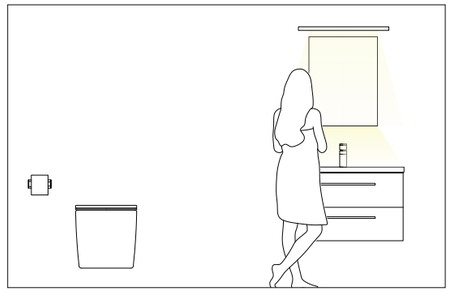
Awake
Allow for morning light to enter bedrooms. Where possible, orient bedrooms to the East. Provide operable window coverings.



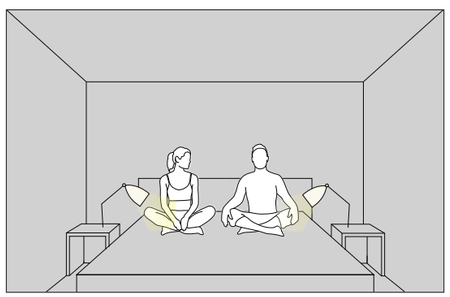
Ambient
Provde warm, indirect light for soft illumination. Avoid artificial light in eyes. Consider dimmable control. Candlelight in the hours leading up to sleep is ideal.



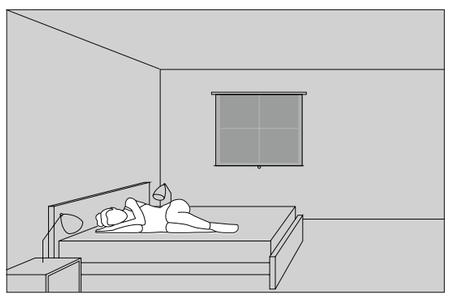
Wash
Provide direct light with high CRI (90+) on face in mirror & lighting over basin. Consider dimmable control & tunable function for day/ night. For example, wall & under-mirror lamps.



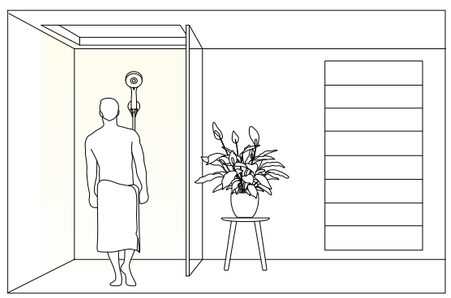
Reading
Provide warm, direct light onto the book. Avoid light in eyes. Consider dimmable control & adjustable positioning. For example, a shaded side-table lamp or wall lamp.



Asleep
Provide complete darkness. If needed, shade windows from external sources of light such as street lights with the use of operable window coverings.



Wash
Provide natural light in bathroom - optimal for true-tone colour rendering & use throughout the day. For example, a skylight over the shower and windows with operable shades.



Chapter 4.3

Light *At Work*

Studies show an average of 30% of the workforce suffer from sleep deprivation and insomnia. It is well proven that poor sleep at night reduces productivity and overall work performance and increases work accidents and absenteeism. Whilst healthy sleeping occurs at night, it starts during the day, where the environments we inhabit shape our circadian rhythm.

Today, the boundaries between the home and the office are blurred. The workplace is now generally regarded as a living space and as such, it needs to accommodate:

- areas for work
- areas for people to come together
- areas for restoration

Through a tailored lighting strategy we can design to cater to the various functions required of the space.

The Licht.de, *'Guide to Human Centric Lighting (HCL)'* report presents four application case studies of how to implement HCL in design projects. Based on this report, we have summarised the key factors and strategies that can be implemented to produce an effective HCL workplace solution.

Identify the aim

- Create an environment that is conducive to work and job satisfaction.
- Support employee's health and well-being.
- Provide an environment that allows employees to function at their best.
- Allow tasks required to be completed well.
- Provide flexibility in use.
- Provide the option for automated control.

Identify the needs

- Performance of the visual tasks required.
- Spaces for focus-work, team work, online work.
- Flexibility in where and how they work.
- Supporting ergonomics and health.
- Adjusting lighting to time of day and time of year.
- Adjusting lighting to the user's individual needs.
- Provide a control system for the whole workplace as well as the individual's workspace.
- Provide pre-set and manual functions.

Strategies

- Smooth transition of light throughout the day and year corresponding to daylight.
- Bright working light for focus and to stay alert (only for short periods, not after dark).
- Window coverings to prevent glare and overheating: Allow for manual opening/ closing.
- Indirect luminaries (General illuminance): Provide pre-set automatic daily routine.
- Direct luminaires (Task lighting): Provide pre-set tuning and allow for manual adjustability for individual control.

The following diagram identifies the Visual and Non-Visual requirements that contribute to an HCL solution for the home.

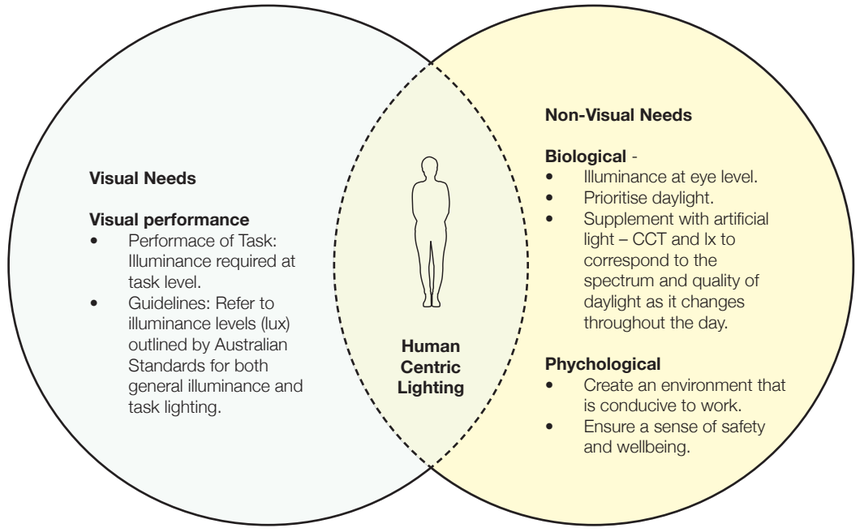


Fig 2.6 - Factors contributing to HCL At Work.

Light Exposure At Work

Graph based on AEST summertime.
The following graph suggests a basic foundation to follow for an HCL solution for the workplace. Here we show the natural course of daylight and how this could inform the artificial lighting for the workplace - bearing in mind typical work hours and the functions required of the workplace. (Ref. Schulz, Andreas. 2018)[1]

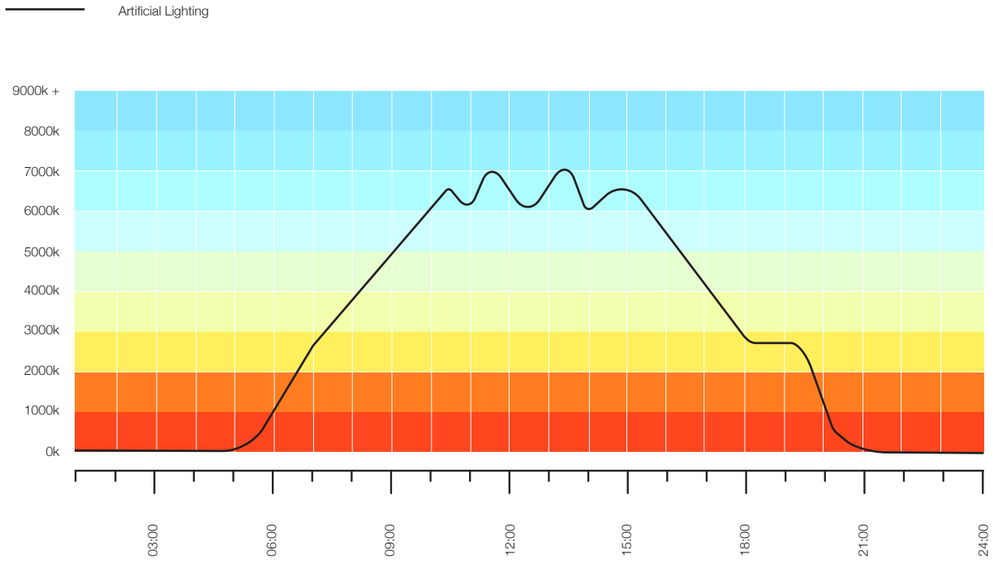
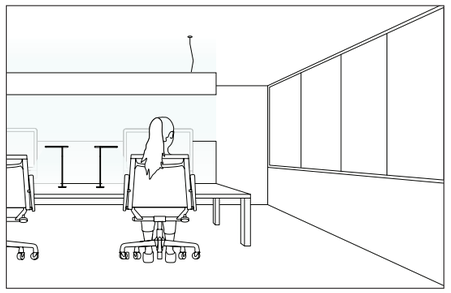


Fig 2.7 - AEST Summer light exposure for HCL At Work.

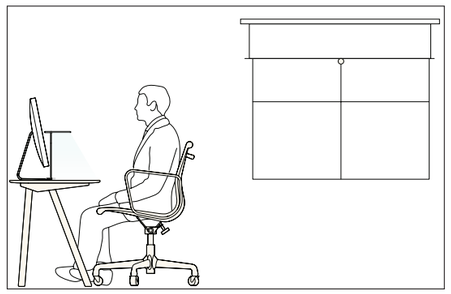
To light the workplace, a successful HCL approach will allow for flexibility and customisation in order to meet the varying needs and work activities of the employees. The following scenes are a series of suggestions of ways in which this could be achieved. Here we suggest the use of daylight where possible, supported by artificial light depending on the task at hand.

At Work:

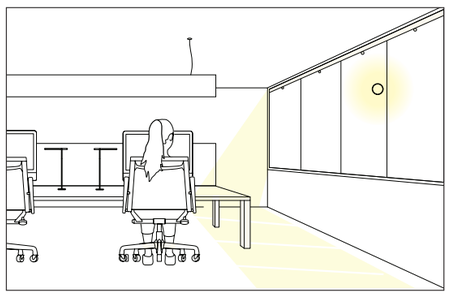
All Lights On
Provide a layering of ambient, task and scenic lighting. Allow for tunable colour & dimmable control. Consider automated control of artificial lights attuned to the course of daylight.



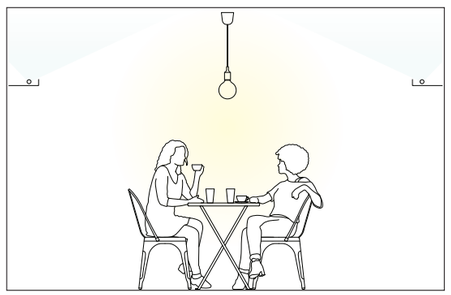
Task
Provide direct light on surface/object on which work is being conducted. Allow tunable colour, adjustable position & dimmable control. Individual to operate. For example, table lamp.



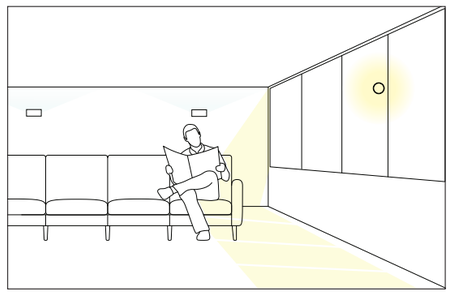
Daylight
Allow daylight to enter and light the space wherever possible. For exampe, providing windows and skylights with operable, translucent window coverings.



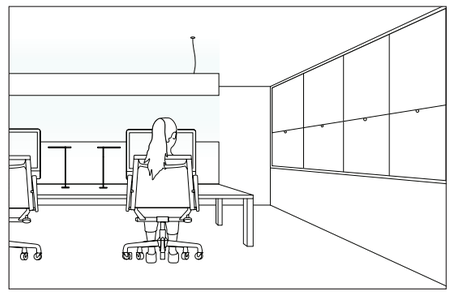
Social
Provide ambient & direct light for conversation. Allow for high CRI (90+), tunable colour & dimmable control. For example, a pendant lamp over a table & indirect up-lit ceiling wash.



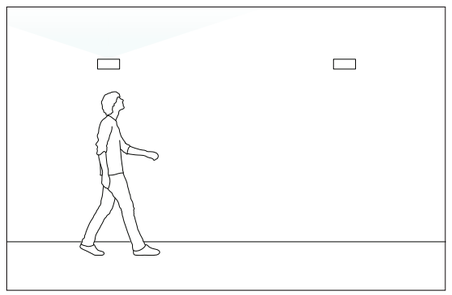
Waiting / Reception
Prioritise & harness daylight. Provide ambient artificial light. Allow tunable colour & dimmable control. Reduce need for window coverings through orientation & external shading.



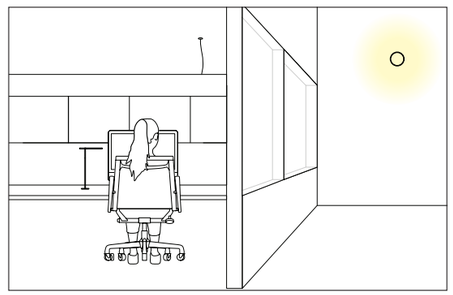
Sun protection
Allow for window covering to provide shading from glare. Consider automated & manual control. Ensure external views can still be seen. For example, translucent roller blinds.



Corridor
Provide enough light to light the pathway. Consider tunable colour for day/night. Allow for dimmable control & motion sensoring. For example, motion detecting up/down wall lamp.



Step Outside
Design to encourage workers to step outside regularly. For example, provide balconies, terraces & close connection to green spaces.



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In Closing

Lighting matters. It impacts our biology and shapes our experience of our surroundings. As designers we have a responsibility to consider this and design in ways to support optimal health and well-being.

Additional Resources

1. **A comprehensive guide to HCL for design:**

   Licht.wissen 21
   'Guide to Human Centric Lighting (HCL)'

   Download accessed via:
   http://en.licht.de/fileadmin/Publications/licht-wissen/1809_lw21_E_Guide_HCL_web.pdf

2. **An inaugural Australian publication presenting current industry practice and research findings:**

   'Unviersal Light;
   An education and design resource for the lighting curious.'

   Download accessed via:
   https://unios.com/universallight/wp-content/uploads/2018/10/UN_Universal-Light_Edition-1.pdf

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