Sensitivity to Light

A Holistic Approach to Light Sensitivity

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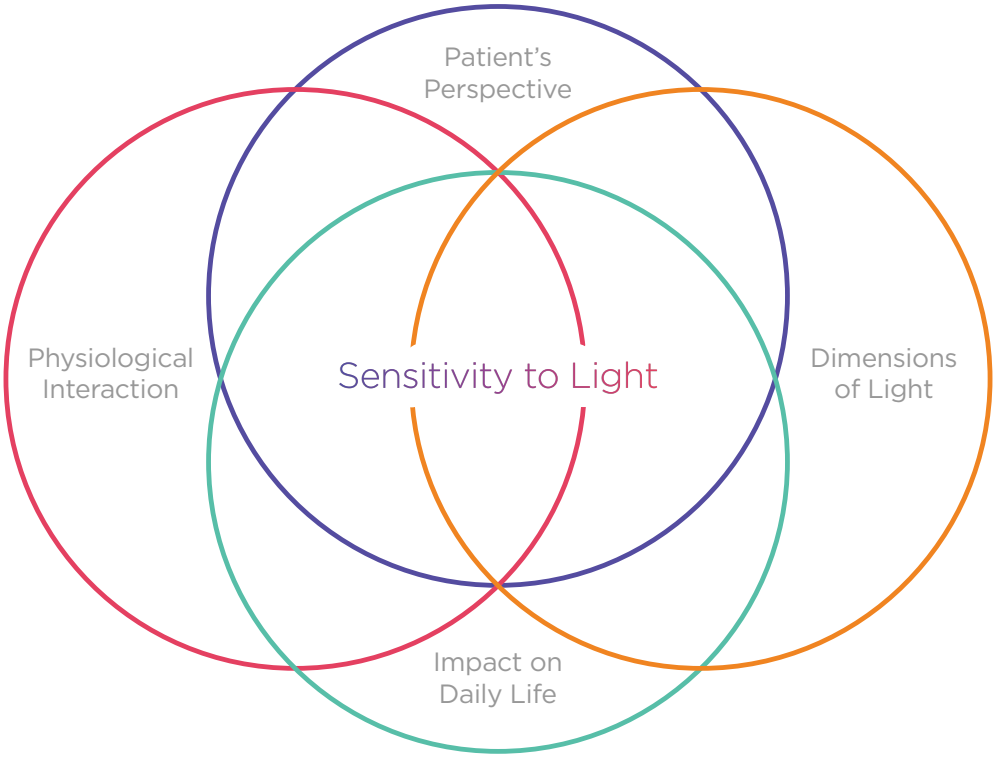
A holistic approach to light sensitivity

Daily exposure to light impacts our visual performance, general health, and wellbeing.[1,2] **Our modern light environment has drastically changed** from previous generations, disrupting the amount of natural and artificial light we were traditionally exposed to. Moreover, the type of artificial light we are subjected to has changed with our rapid conversion to LED lights and their increased blue light and brightness.

This overexposure to artificial light day and night, and underexposure to natural light, can negatively affect our health[3] and is a key public health concern (WHO 2014). A **holistic approach** that considers both the dimensions of light and how the eye interacts with light is essential to understand a person's sensitivity to light and its impact on their daily life. By sharing our knowledge on light sensitivity, it is our desire that it will **help eyecare professionals in their diagnosis and treatment of patients.**

Holistic Approach – Sensitivity to Light



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A Patient's Perspective of Sensitivity to Light

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Relating to light

Modern lifestyles and technological advancements have changed our light environments

people declare they experience sensitivity to light

Light is essential to sight and life. **Our physiological need for light to see is equaled by our psychological need for color, beauty, and wellbeing to live.** As artificial light has proliferated so has our exposure to it, with 99% of the continental U.S. and Europe experiencing nighttime light pollution.[4]

Our lifestyles have also fundamentally changed as Europeans now, on average, spend 90% of their time indoors.[5] This is compounded by the amount of time spent on digital devices—in fact, U.S. adults spent 6.3 hours per day using digital media in 2018.[6] The consequence is that our natural circadian cycle is disrupted and our eyes are increasingly more sensitive to light and face more demands from artificial and constantly changing sources. We are not exposed to enough natural daylight of high spectral quality. As a result, **nine out of 10 people declare they experience sensitivity to light.[7]**

Emotional & Social Impact of Sensitivity to Light

People who experience sensitivity to light are impacted physically, emotionally, professionally, and socially. A loss of visual performance or light-associated discomfort can impact daily life. For example, driving is a common occurrence where visual performance and safety can be impaired. Additionally, other aspects of life can be affected by reductions in light-related visual performance. For instance, in dim light environments, older adults show alterations to measures of gait.[8]

Even so, it isn't just special activities or groups that are impacted; 86% of working Americans experience sensitivity to light in the workplace, and 74% say that sensitivity to light negatively affects their ability to do their jobs.[9]

People suffering from severe sensitivity to light experience ocular pain than can have a significant impact on their quality of life. This pain occurs during exposure to light levels required for functionality and productivity and can result in physical and social isolation, along with loss of function.[41]

Patients may express their experience with light as impacting them in the following ways:[10]

Socially

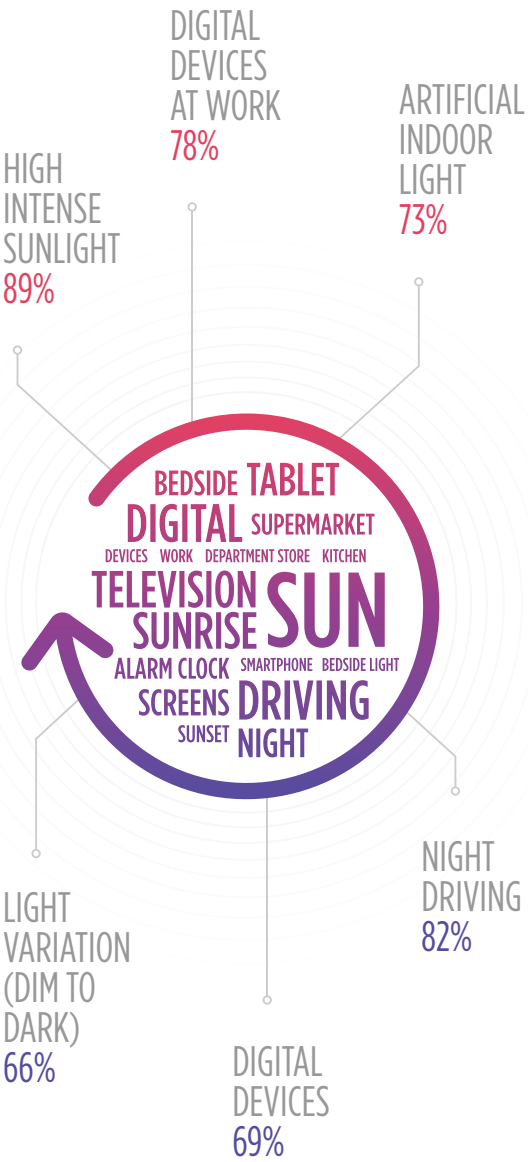
"My friends really like to lay down in the sun. I am always the person that is in the shade or by the tree."

Emotionally

"The dreaded headlights at night. I feel stuck, scared, and blinded, which makes me feel weak and susceptible."

Light in real life

Figure 1:
A Day in the Light: Percentage of people that report these situations as troublesome[11]



People don't often think about their relationship to light—or sensitivity to it—until they find themselves in situations where the light environment is uncomfortable or visually disruptive. As people are constantly exposed to light, from various sources and from all directions, there are numerous light conditions in which a person's sensitivity to light can manifest throughout their day **(Figure 1)**. The rapid evolution of our light environments impedes the natural defense mechanisms of the eye to efficiently cope with glare.

Light's impact on comfort & vision

The light associated with a person's physiological sensitivity can be described in two general categories: glare that causes **discomfort** and glare that causes **disability**.

Disability glare is a physiological glare that impairs vision. It is mainly caused by intraocular light scattering (straylight) that reduces the contrast of retinal images by spreading a veiling luminance across them.[12]

Discomfort glare is a psychological glare that causes annoyance. Long-term exposure to discomfort glare may lead to visual fatigue, including asthenopic symptoms (eye strain). This can include itching, tearing, oversensitivity to light, blurring, visual tiredness, headache, heaviness of eyelids, redness, and shooting pain.[13, 14]

There are other risks to light exposure beyond disability glare or discomfort glare. Some light exposure is harmful in the long term and protection is needed regardless of a person's sensitivity to light. **Unprotected UV and harmful blue light exposure accelerates eye ageing and may favor eye damage or lead to irreversible pathologies.[42]**

Dimensions of Light

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Light intensity

Light is all around us, a constant yet dynamic presence. A multitude of natural and artificial lights make up our ever-changing light environments.

> "Some lights are pleasing and make me happy, relaxed, content, and calm. Other kinds of light make me stressed, frustrated, unhappy, and affect me physically. Each kind of light affects me in a different way."
>
> Sharon, United States[10]

Through over 100 scientific articles and both qualitative and quantitative consumer studies, we've mapped a multitude of light to better understand it and peoples' relationship to it – both the positive and negative aspects. In this process, we've identified **four dimensions of light** that can be measured and have an impact on a person's sensitivity to light. **A combination of these four dimensions defines all the light around us.**

The light level, commonly named as light intensity, varies in a very rapid manner all day long. We receive 100 to 200 times higher light irradiance outdoors compared to artificial lighting without any windows. The position relative to windows can also influence indoor exposure to natural light: next to a window light levels are only 10 times lower than outdoors, while in the middle of a room they may be 200 times lower.

Light intensity outdoors also depends on geographical location, season, time of day, and local weather. In France, there is for instance a 2.5 times ratio in irradiances between the summer and the winter.[15]

Our eyes are subjected daily to a huge set of light intensities they need to manage. Bright daylight is particularly demanding for the eyes and favors discomfort glare.

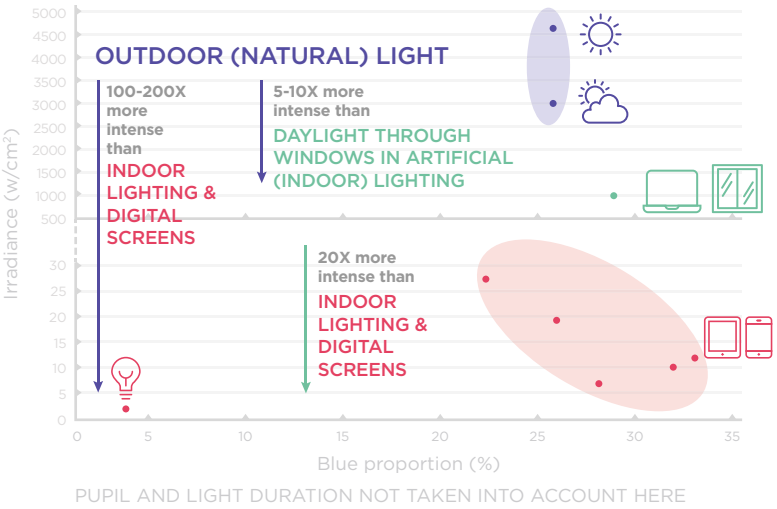
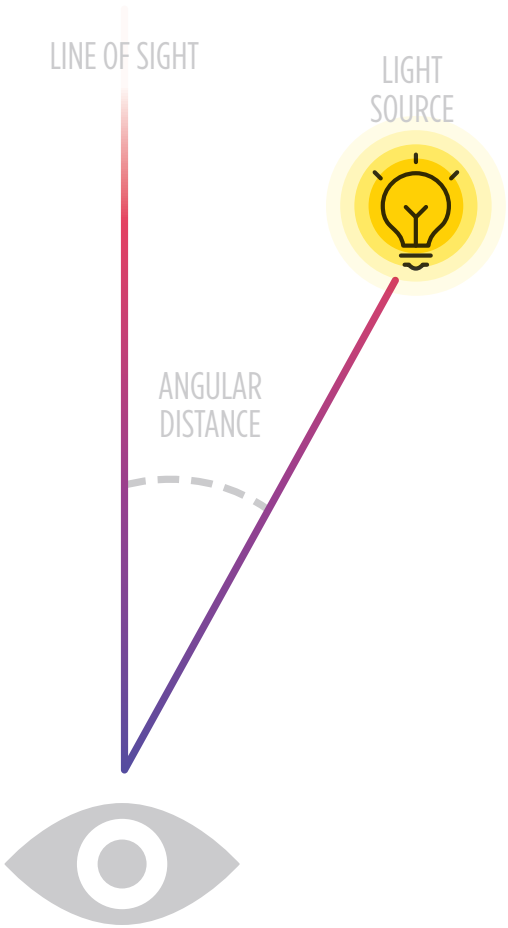


Figure 2: Comparison of light levels, natural light vs. common artificial lights

Spatial distribution of light

Figure 3: Angular distance between light source and observer



The spatial position of light sources and their size have a huge influence on the quantity and quality of light received by our eyes. In 1995 the CIE Technical Committee 3-13 developed a practical discomfort glare evaluation system for indoor lighting, which resulted in the Unified Glare Rating (UGR).[16]

UGR highly depends on the spatial distribution of light: the source luminance in the direction of the observer, the solid angle subtended by the source at the observer's eye, the angular position of the source in the observer's field of view and the background luminance. **(Figure 3)**

The smaller the light source, the higher the discomfort glare. Point-like or non-uniform light sources, such as night driving, are particularly troublesome in our daily life and may favor disability glare. High contrast of luminance, for instance a bright digital device in a dark environment, is also a common source of glare and discomfort.

Temporal factors

Our light environment is not static, it constantly changes over time and highly depends on the activities of individuals and the exposure to artificial light from indoor lighting and digital sources. This temporality of light or the time element of light can impact vision. A light source may be present for a short or long period of time, or we may move from one lighting condition to the other. Flashing light or brutal light changes are more uncomfortable due to retina time adaptation.

Spectral properties of light

Light usually refers to visible light for the human eye, ranging from 380 to 780 nm, from blue to red light.

UV radiation

Ultraviolet radiation is beyond the visible spectrum. It is divided into UVB (280-315nm) and UVA (315-380nm). Exposure to UV radiation is well established as a major cause of eyelid malignancies, photokeratitis, climatic droplet keratopathy, pterygium, and cortical cataract.[21, 22]

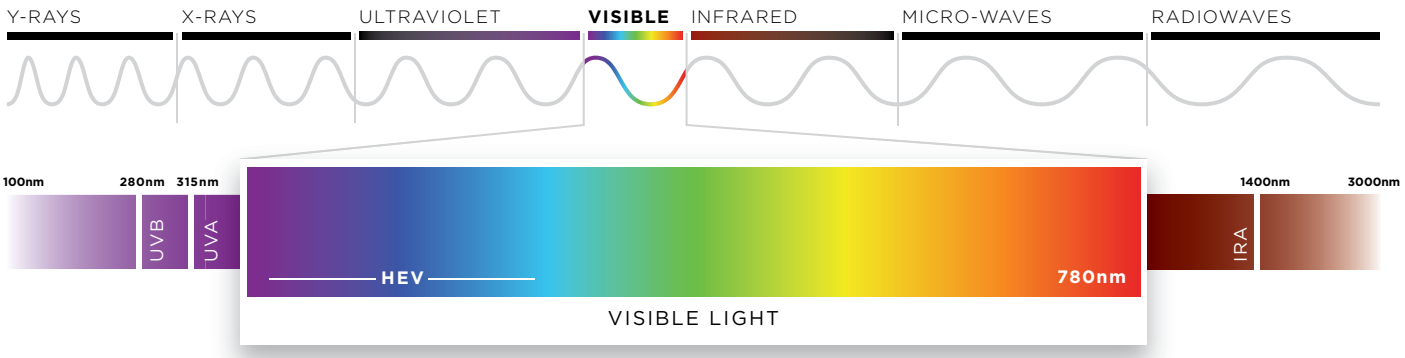
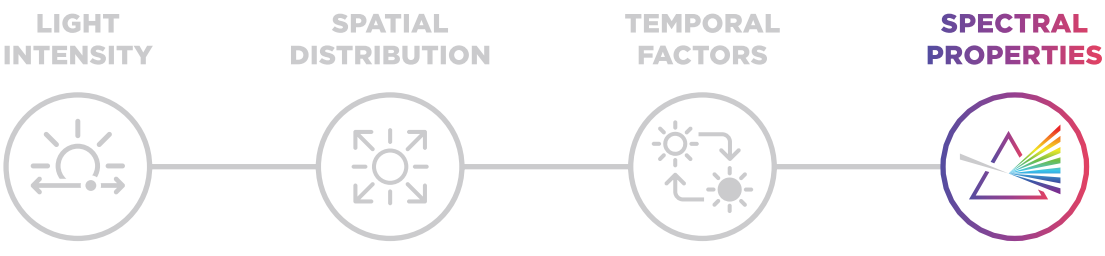


Figure 4: Visible light in the electromagnetic spectrum



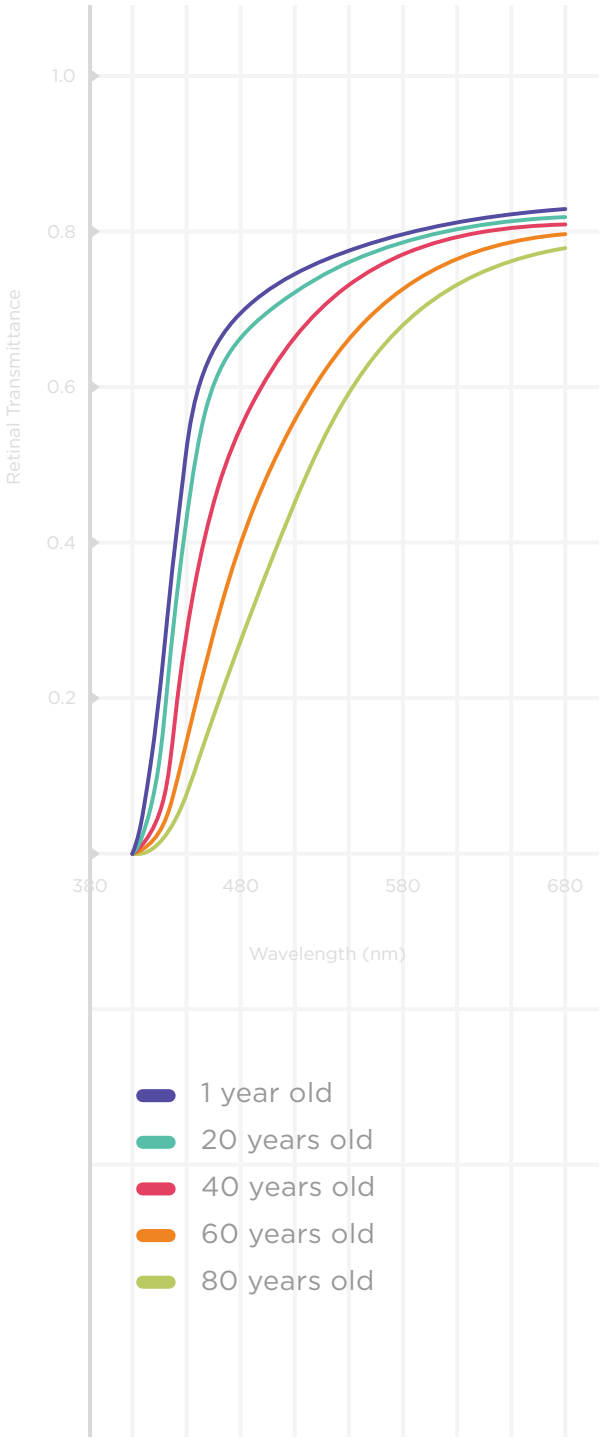


Figure 5: Retinal transmittance with age

Blue light

Blue light, ranging from 380 to 500 nm, is the most energetic part of visible light entering the retina. While UV transmittance is blocked primarily by the cornea and crystalline lens in healthy adults, blue light passes through the eye structure, potentially causing harm to the retina.

The amount of blue light reaching the retina depends on the age of the eye as, during a lifetime, there is a slight yellowing of the crystalline lens that would typically provide some absorption in the blue-violet region as a natural protector. But with age, antioxidant defense mechanisms decrease. **(Figure 5)**

Accumulating experimental evidence has indicated that prolonged exposure to blue light contributes to retinal ageing and may cause or enhance retinal damage. Particularly, it has been demonstrated that exposure to blue-violet light between 415-455 nm can induce irreversible cell death in the outer retina in simulated moderate daylight conditions.[17, 18, 19]

Beyond its cumulative long-term effects on visual health, a growing set of scientific papers suggest **blue light favors glare**. Therefore, filtering blue light may improve visual functions in high glare situations.[20]

Physiological Interaction with Light

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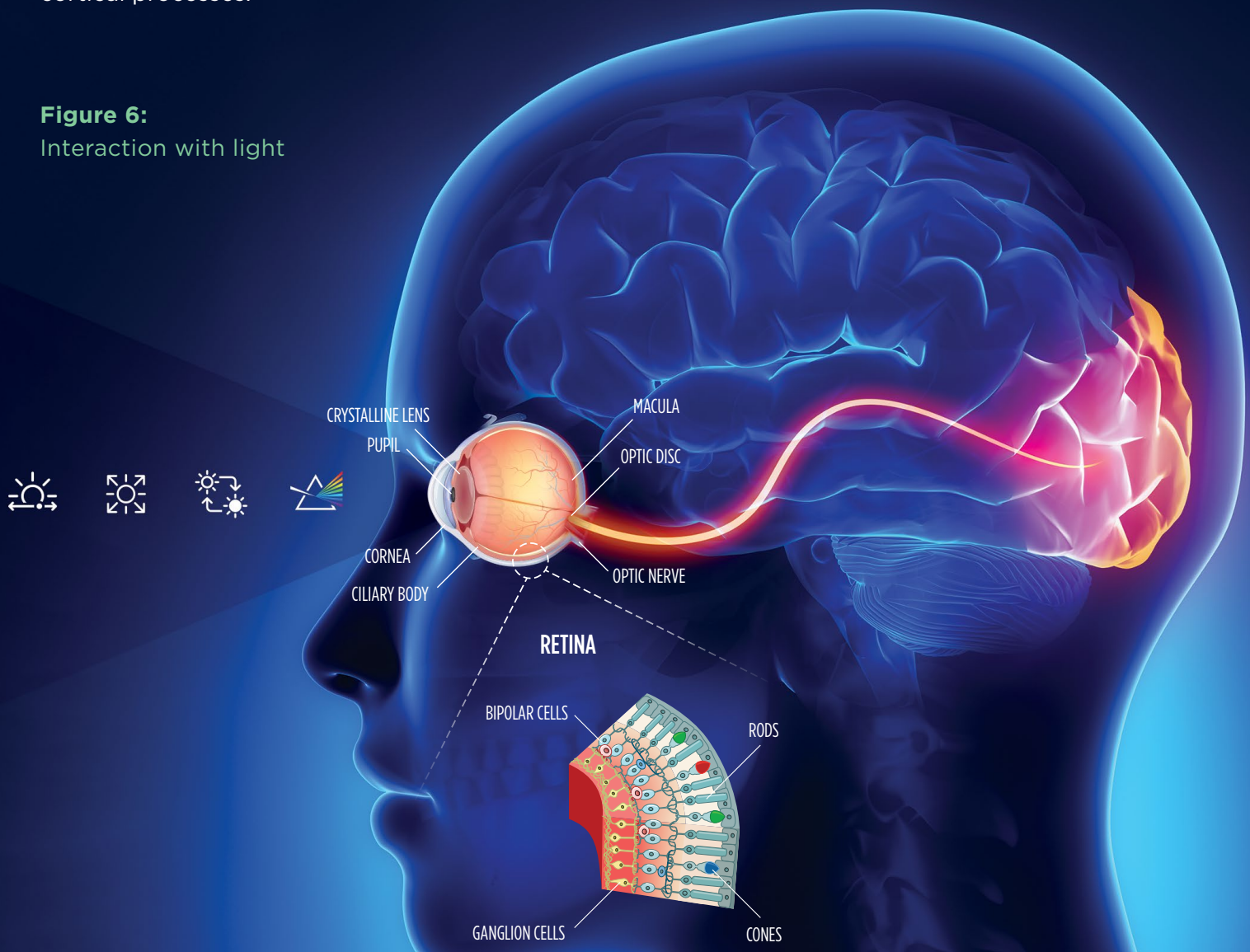
The eye receives millions of billions of photons each day. Likewise, all day long the eye is adapting to changes in the light environment. Our eyes have natural protections against light: the eyelids, the pupil acting like a diaphragm in bright light conditions, the filtering of the cornea and the crystalline lens to protect the retina, cortical processes.

But drastic and rapid changes to our light environments can exceed our eyes natural coping mechanisms. Light is analyzed through the retina and the brain. Two types of photoreceptors are involved: the visual photoreceptors, cones and rods, but also the non-visual photoreceptor, melanopsin-based retinal ganglion cells.[23] Glare is the result of the light situation, the eye & brain response to light and the lifestyle and tolerance of the patient.

Figure 6:
Interaction with light



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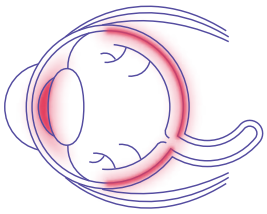
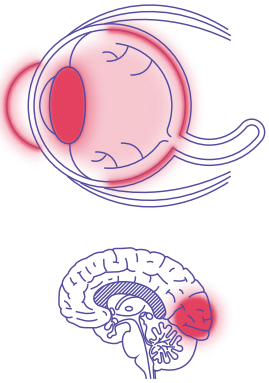
Eye's response to light & the impact on patient's experience

Figure 7: Dimension of light impact on eye function and response

Each light situation is a particular combination of the four dimensions of light and have a unique interaction with our eyes and brain. **Figure 7** lists each dimension of light, the main associated eye responses, and the impact on patient's experience.

	The Eye's Response	Impact on the Patient's Experience
 Intensity  	The **pupil** either constricts or dilates, regulating the intensity of light reaching the **retina**. In bright light conditions the pupil is smaller. Natural aversion response for exposure to bright light includes, pupillary constriction, eye movements, squinting and in some cases blinking. Photostress occurs when **rod** and **cone photopigments** are excessively bleached, reducing **retinal** sensitivity. Non-visual photoreception contributes to discomfort glare, with **RGCs** transmitting irradiance data to higher **cortical centers**, which helps to set adaptation luminance.[24] Responses in certain **cortical areas** are higher for hypersensitive people.[25]	The higher the intensity, the higher the discomfort and/or disability glare. Saturation of photoreceptors can produce afterimages, which change color ("flight of colors") as photopigments regenerate.

Spatial



Eye scattering impacts visual function in glare conditions; it's dependent on the size and position of the source. Scattering occurs in the cornea, lens, and vitreous humor, and it increases when their transparency is compromised, as in cataracts.

Light scattering (straylight) involves a veiling luminance on the retina that decreases image contrast.

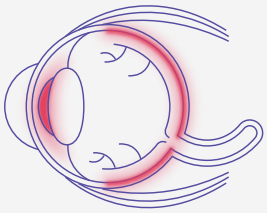
High spatial contrasts of luminances result in more sophisticated integrative retinal and cortical processes.[26, 27]

The smaller the size or closer the light source, the higher the discomfort.

The higher the eye scattering, the higher the disability glare.

High spatial contrasts of luminances favor higher glare and discomfort.

Temporal



Moving from light to dark **rod pigments** are bleached out and they are initially nonfunctional, while the cones cease functioning in low intensity light. Once in the dark, the sensitivity of the retina increases over time (this can take up to one hour). During this adaptation process, reflexive changes occur in the **pupil** size.

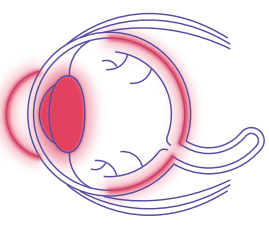
With brilliant light exposure **rods** and **cones** are both stimulated and large amounts of the photopigment are broken down instantaneously, producing a flood of signals resulting in vision loss. Adaptation occurs in two ways: (i) the sensitivity of the **retina** decreases dramatically, and (ii) **retinal neurons** undergo rapid adaptation inhibiting rod function and favoring the **cone system**.

After exposure to bright light, vision loss is often experienced when moving into dark or dim situations, and a recovery period is needed.

Brilliant light exposure can impair vision and producing afterimages.

Previous short- and long-term light exposure impacts the perception of light sensitivity and tolerance to discomfort.

Spectrum



Pupil behavior is wavelength dependent: higher pupil constriction and sustainability in blue-green light, as pupil light reflex is highly dependent on melanopsin-based retinal ganglion cells.

Energetic **UV** radiations are absorbed by the **cornea** and by the **crystalline lenses**. **Blue light** is the most energetic light reaching the **retina**.

Rods, cones & retinal ganglion cells have different spectral sensitivities.[12]

Long-term exposure to UV and harmful blue light can cause damage to the eye (eye ageing).

Post-cataract patients with clear intraocular lenses (IOL) are more sensitive to discomfort glare.

Blue light favors **discomfort glare**.

Impact on Daily Life

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Light driven behavior

In daily life, we are exposed to a variety of different light conditions during our day. As a result, our light environments are not static, but are constantly changing and highly variable across a range of timeframes. Additionally, a person's lifestyle and daily activities can greatly affect their exposure to light. Below are 6 of the most common situations people say are troublesome. For each situation, we have identified the type of light, the level of dimensions, the physiological response, and the question you can ask to help assess whether or not this is a situation experienced by your patient.

4D COMPONENTS: High intensity levels

INTENSITY SPATIAL

SPECTRUM TEMPORAL

Intensive sunlight

People will find themselves needing to close their eyes or squint when exposed to harsh sunlight that is too intense compared to their retinal resistance. If the exposure is brief, an adaptation to the luminous flux occurs. Whereas if it is prolonged, there will be saturation of the retinal processes and blinding glare will be experienced.[12]

TYPE OF LIGHT: Outdoors, natural
PHYSIOLOGY: Photoreceptor saturation and blinking or squinting as a reflex to protect the eye
ASSESSING QUESTION: Do you squint when you walk around in bright sunlight?

4D COMPONENTS: Flashing lights, point-like sources, high contrast of luminances, high blue component in LED headlights

INTENSITY SPATIAL

SPECTRUM TEMPORAL

Night driving

Vehicle headlights can result in discomfort and/or disabling glare at night. Headlights are a focal or point-like source of artificial light – the smaller the size, the more visual discomfort they will produce, and the closer they are the more disabling they will be. Individuals suffering from discomfort/disability glare while driving will transition from low light levels (nighttime) to a sudden peak of light intensity (headlights). The variation of comfort and vision will depend on the luminous intensity before the stimulation.

TYPE OF LIGHT: Outdoors, artificial (headlights), nighttime
PHYSIOLOGY: Retinal light and dark adaptation. Disability, vision recovery time[43]
ASSESSING QUESTION: Does light often make you feel uncomfortable when driving at night?

4D COMPONENTS: Low rendering-color index, high blue component; non uniform light sources, high-intensity levels for indoor lighting

INTENSITY SPATIAL

SPECTRUM TEMPORAL

Harsh indoor light

There is a high correlation between the luminance of a glare source (i.e., intensity) and the degree of discomfort. Discomforting glare perception also depends on the spatial situation of the observer in relation to the glare source. Furthermore, the more peripheral the position of the glare source, the lesser the perceived discomfort. There is also a rising concern that LED based light sources may cause more glare since they possess the characteristics of high surface luminance, small emitting size, and special spectral power distribution due to its peculiar emitting principle.[44]

TYPE OF LIGHT: Indoors, artificial

PHYSIOLOGY: Retinal and pupil behavior to manage the spectral power distribution in the visual field (position and size of the source from the line of vision)

ASSESSING QUESTION: Are you bothered by harsh indoor lights?

4D COMPONENTS: Non-uniform light sources; poor quality, high blue component

INTENSITY SPATIAL

SPECTRUM TEMPORAL

Computer & digital screens

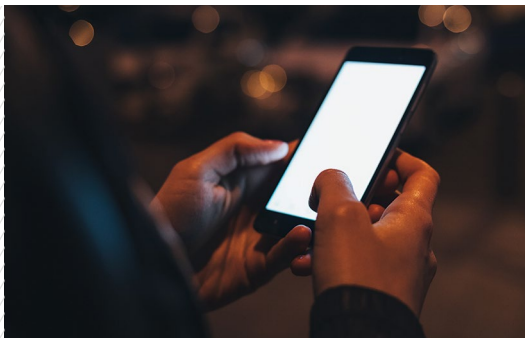
Computer screens, LEDs, smartphones, and a whole array of connected devices have all had an impact on our everyday lives. Both exposure time and proximity to the source impact the visual discomfort. Indeed, 26% of people complain after using a smartphone due to the brightness of the screen.[28]

Although the light emitted by most LEDs appears white, LEDs have peak emission in the blue light range (400-490 nm) which could be harmful.

TYPE OF LIGHT: Indoors, artificial, computer screens, LEDs

PHYSIOLOGY: Spectral sensitivity (blue light), Proximity of the source

ASSESSING QUESTION: Do you often feel like your eyes become strained while (or after) using your computer?



4D COMPONENTS: High contrast of luminances

INTENSITY

SPATIAL

SPECTRUM

TEMPORAL

Dimming digital screens

Luminance contrast (dark background vs bright light) is the situation that generates the most visual discomfort. This is not only related to the absolute intensity of the light, but to the relative intensity between the object and its background. In this situation, it is common and easy to be able to directly adjust the brightness of the screen to optimize its comfort or use filters that allow blocking certain components of the spectrum.

TYPE OF LIGHT: Indoors, artificial light
PHYSIOLOGY: Luminance contrast management by the retina, Dynamic pupil and retina processes according to the spectrum and intensity distribution
ASSESSING QUESTION: Do you sometimes dim your smartphone screen because you are bothered by the brightness of the light?

4D COMPONENTS: Light transition

INTENSITY

SPATIAL

SPECTRUM

TEMPORAL

Light variation

If we go from the outdoors on a bright sunny day into a dimly lit room, we are hardly able to see our surroundings at first. As time goes by, however, we gradually recover our vision. This phenomenon is known as “dark adaptation”, or the ability of the eye to become more visually sensitive after remaining in darkness for a period of time. On the other hand, light adaptation occurs when we move from the dark into bright light. The bright light momentarily dazzles us and all we see is white light because the sensitivity of the receptors is set to dim light.

In both scenarios, time is needed to regain comfort and a good visual performance. This time is dependent on several factors, including the light level before the light variation and the significance of the light jump (sudden intensity variation). The retina takes longer to adapt again to low light flux, in those cases we often refer to the term “vision recovery.”

TYPE OF LIGHT: Outdoors to indoors, natural vs. artificial
PHYSIOLOGY: Retinal light adaptation, Vision recovery time according to the light intensity gap
ASSESSING QUESTION: If you’ve been outdoors on a bright day, do you find it difficult to see properly for a few moments after you’ve gone indoors?

Additional factors that impact light sensitivity

Although light can be described by more or less known physiological processes, the feeling of discomfort remains a psychological sensation that may be influenced by a wide range of factors related to personal characteristics and environmental conditions. In addition to utilizing the assessing questions for the most common situations above, you could also consider using a lifestyle and medical questionnaire to assess habits and conditions that contribute to light sensitivity.

New research suggests that **time of day, season, and culture** are also potential factors that may influence a person's sensitivity to light.[39, 40]

Age-Related

With age, some of the most prominent changes include the reduction of retinal illumination due to opacification and yellowing of the lens, particularly in shorter wavelengths, due to reduction in pupil size[29, 30, 31] and an increasing of the straylight, particularly due to cataracts.[32, 33, 34] Children also react differently to light: their cornea and crystalline lens are more transparent, their pupil size is bigger for a given light flux and their antioxidant defenses are not mature.

Existing Illnesses

Other common causes of light sensitivity include ocular surface alteration (corneal abrasion, uveitis, refractive surgery, dry eye), retina disease (ARMD, Glaucoma), and central nervous system disorders such as meningitis.

Medications

Medications reported to induce sensitivity to light include the antiarrhythmic drug amiodarone, anti-ulcer agents, nonsteroidal anti-inflammatory drugs, and tetracyclines.[35] Decreased tolerance to source luminance from artificial lighting has also been reported after ingestion of caffeine.[36]

Task Difficulty

The perceived discomfort glare is influenced by the presence and the difficulty of a task, although it is not yet sure whether more difficult tasks generate higher or lower discomfort glare perception.[37]

Chronotypes

People with different behavioral manifestations of circadian cycles (chronotypes) may have different light sensitivities. Earlier chronotypes have greater tolerance to luminance from artificial lighting at all times of day.[38]

Key takeaways

- **9 out of 10 people experience sensitivity to light.**[7]
- A **holistic approach** that considers both the **dimensions of light** and how the **eye interacts with light** is essential to understanding a person's **sensitivity to light** and its **impact on their daily life.**
- A person's **sensitivity to light can manifest throughout their day** and affect them physically, emotionally, professionally, and socially.
- Our modern light environments **impede the defense mechanisms of the eye to cope with glare,** causing **discomfort** and **disability.**
- **Each light environment** is a particular combination of **four measurable dimensions of light** and have a **unique interaction** with our eyes and brain, but there are **six light situations people report as most troublesome.**
- Professionals can **assess a person's sensitivity to light by asking questions** about their daily life related to the **most troublesome light situations** as well as conducting a lifestyle and medical questionnaire.

Light Intelligence

As a professional, there are many ways to address light sensitivity. Helping patients assess their level of light sensitivity and educating them on the importance of proper light management is the essential first step. Prescribing a light intelligent solution that provides the appropriate level of light protection for their lifestyle is next. For many light sensitive patients, *Transitions* light intelligent technologies are the ideal solution because they help provide the protection, comfortable vision, and style they desire and are available in the widest range of products to cater to all patient types.

Conclusion

The light around us consists of multiple lights including a vast range of artificial light and natural sunlight. Each dimension of light elicits a unique response from the eye that can have a measurable impact on a person's daily life. As a result, discomfort or even pain associated with light is a common symptom. In fact, 9 out of 10 people declare they experience sensitive to light. Utilizing a holistic approach, a person's light sensitivity can be easily addressed by asking questions related to the most common situations that people report light as bothersome, educating them on the importance of light management, and then prescribing a light intelligent solution appropriate to their lifestyle.

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