Why is blue tinted backlight better?

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Abstract. Fact: Blue images always look sharper than white images to the user. Siemens Display Technologies implemented blue backlights in its flat panel display product line and had the same feedback from its customers: bluish pictures look brighter. Therefore we wanted to research this theme and try to explain this unique "feature" from a more theoretical point of view. We can explain why, under interior light conditions, the eye is more sensitive in the bluish domain of the color spectrum where both spatial resolution and contrast resolution are optimized. Furthermore, the eye comfort is improved in this configuration.

Keywords: bluish color temperature; blue-tinted backlight; liquid crystal display.

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1. Introduction

At Siemens Display Technologies, we develop displays, currently liquid crystal displays (LCDs). Our display systems are now state of the art (Panel, board technology, etc.). That is why we are looking for other opportunities to improve our displays. What are the best display-system conditions on which a radiologist can rely?

We referred to an old-time observation: for more than 100 years, lighting users have often found that their sense of brightness does not match with light meter values. Areas lit by lighting with bluish tint appear brighter than the same areas lit by lighting with more of an orange or reddish tint even though a light meter may indicate the opposite.

Some more recent results also confirm this. At Siemens Display Technologies, we also have been witness of that with display users: looking at pictures with same contrast ratio (CR), same black and white levels, all of them maintain that the bluish picture is brighter to them, and has better CR and resolution, even if, objectively, the measurements are the same.

What is the explanation therefore? It must have something to do with the eye physiology. Recent scientific research can explain this feature, based on the eye's physiology.

That is what this document is presenting. The first paragraph deals with some pre-requisites from the visual system behaviour. This information is the basis for the explanation as to why a blue tinted display offers accuracy and comfort advantages to its user.

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2. Eye physiology

The retina is a light-sensitive membrane at the back of the eye. The retina contains millions of very tiny light photoreceptors.

Photosensitive cells called rods and cones in the retina convert incident light energy into signals that are carried to the brain by the optic nerve.

In the middle of the retina is a small dimple called the fovea or fovea centralis. It is the center of the eye's sharpest vision and the location of most color perception.

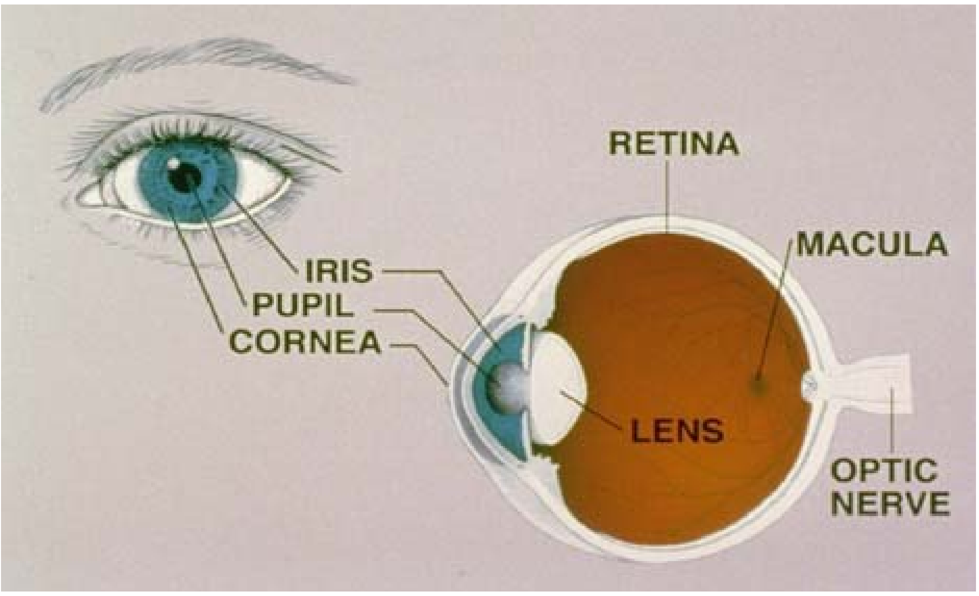


Fig. 1. Eye physiology.

"A thin layer (about 0.5 to 0.1mm thick) of light receptor cells covers the inner surface of the choroid. The focused beam of light is absorbed via electrochemical reaction in this pinkish multilayered structure. The human eye contains two kinds of photoreceptor cells; rods and cones. Roughly 125 million of them are intermingled non-uniformly over the retina. The ensemble of rods(each about 0.002 mm in diameter in some respects has the characteristics of a high-speed, black and white film(such as Tri-X). It is exceedingly sensitive, performing in light too dim for the cones to respond to, yet it is unable to distinguish color, and the images it relays are not well defined."(Hecht)

"In contrast, the ensemble of 6 or 7 million cones (each about 0.006 mm in diameter) can be imagined as a separate, but overlapping, low-speed color film. It performs in bright light, giving detailed colored views, but is fairly insensitive at low light levels."(Hecht)

2.1 Photosensors performances

The rods are more numerous, some 120 million, and are more sensitive than the cones. They are incredibly efficient photoreceptors, adapted for the dark surrounding (scotopic vision). They are more than one thousand times as sensitive as the cones: e.g. they can be triggered by individual photons under optimal conditions.

As a result, they allow for the ability to distinguish 2 kind of dark gray levels for instance. When active, a better contrast resolution is achieved.

Furthermore, they are better motion sensors than the cones.

However, the rods are not sensitive to color. The 6 to 7 million cones provide the eye's color sensitivity.

The Fovea Centralis exclusively contains cones (see fig.2). That is why the cones visual resolution is much better.

Another reason is that the cone cells are connected to one ganglion cell only, whereas several rod cells are connected to one ganglion cell.

The rods provide the resolution of details.

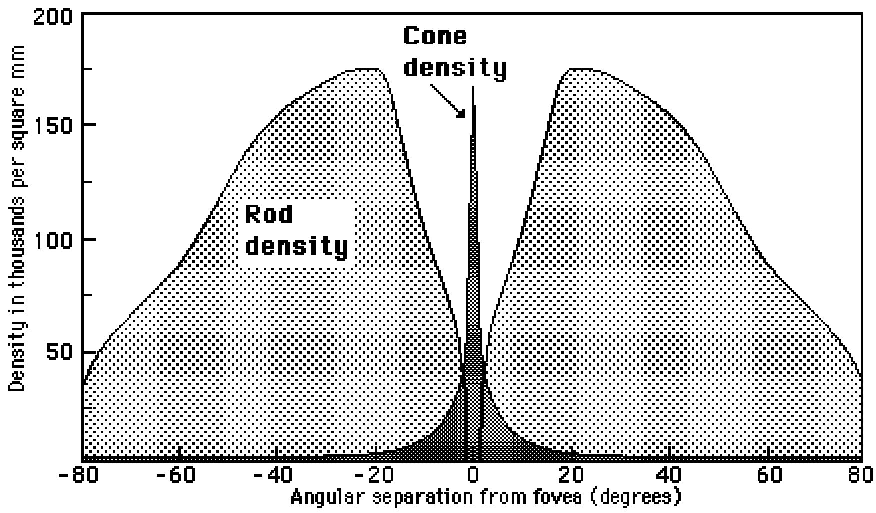


Fig. 2. Cone and rods repartitions, apart from the fovea.

2.2 Photosensors & blue light response

How do cones respective to rods react to blue light? Do they react differently to blue or white pictures?

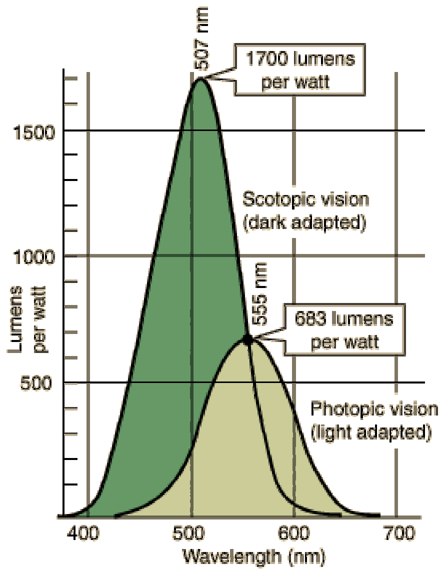
The 6 to 7 million cones can be divided into "red" cones (64%), "green" cones (32%), and "blue" cones (2%) based on measured response curves. They provide the eye's color sensitivity. (see fig. 3 (b))

However, the blue sensitivity of our final visual perception is at least comparable (and is even better) to that of red and green, suggesting that there is a somewhat selective "blue amplifier" somewhere in the visual processing in the brain. There must be some boosting mechanism.

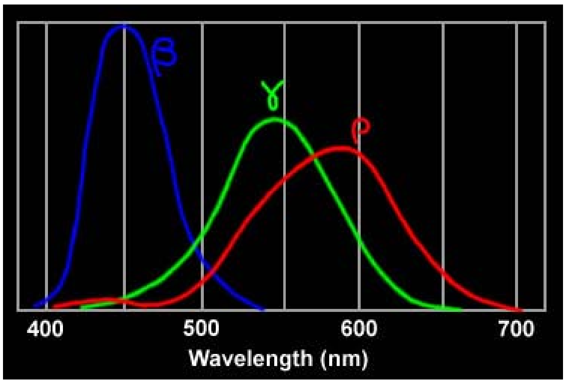
As far as the rods are concerned, the light response of the rods peaks sharply in the blue; they respond very little to red light. The rod sensitivity is shifted toward shorter wavelengths (507 nm) compared to daylight vision. (see fig. 3 (a))

This leads to some interesting phenomena. Here, the example of the red rose at twilight is used to become more familiar with the process. In bright light, the color-sensitive cones are predominant and we see a brilliant red rose with somewhat more subdued green leaves. But at twilight, the less-sensitive cones begin to shut down for the night, and most of the vision comes from the rods. The rods pick up the green from the leaves much more strongly than the red from the petals, so the green leaves become brighter than the red petals!

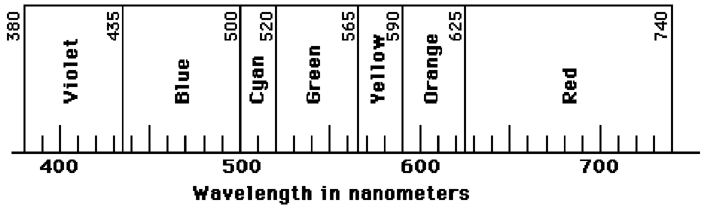
This phenomena arises from the nature of the rod-dominated dark-adapted vision, called scotopic vision.



3)a) Rods and cones sensitivity curves



3)b) Cones sensitivity curves (R, G, B)



3)c) Wavelength scale.

Fig. 3. Sensitivity curves: a) depending on the ambient condition (dark surrounding or not); b) Cones sensitivity curves for red, green and blue cones. c) wavelength scale.

Key ideas paragraph 2:

- Retina = Light sensitive membrane at the back of the eye
- Retina contains 2 major photoreceptors: cones and rods.
- In the very central portion of the retina (fovea): only cones.
- In the rest of the retina: both rods and cones: 10 times more rods than cones
- Both sensors present unique advantages (contrast or details resolutions)
- For day-vision: 3 color sensitivity curves, with selective "blue amplifier" for the blue cones.
- For dark vision: rods response has a unique peak in the blue range

3. Diagnostic conditions: how does the eye work?

3.1 Vision types

There are 3 vision types:

- Scotopic vision: this is the scientific term for human vision "in the dark", below 0.034 cd/m². The human eye uses rods to sense light. Since there is a single absorption maximum at a wavelength of 507 nm, the scotopic vision is color blind.

- Photopic vision: this is the scientific term for human color vision under normal lighting conditions during the day, in the range above 3.4 cd/m².

- Mesopic vision: Mesopic vision is the scientific term for a combination between photopic vision and scotopic vision in low, but not quite dark, lighting situations, concretely in the intermediate range (between 0.034cd/m² & 3.4cd/m²).

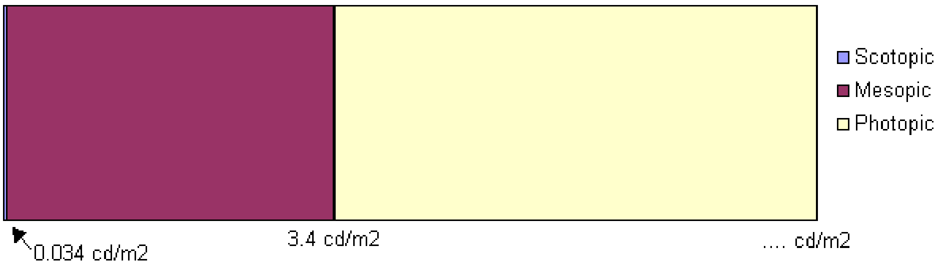


Fig. 4. repartition of the 3 vision types.

3.2 Consequences in medical viewing conditions

The utilization of the mesotopic vision, in addition to the well-know photopic and scotopic visions, has a huge impact on our research: it means that at interior light levels, the rods are not disabled and are functioning quite well. They contribute to the perception of the brightness.

These findings correspond to the viewing conditions that are used in medical reading rooms or diagnostic rooms.
For medical image reading, both photosensors, the rods and the cones, are active and combine their properties as far as how the image is perceived. They combine their performances and their sensitivity curves.

How does that affect image viewing?

4. Advantages of blue-tinted backlight

4.1 More efficency

As discussed in paragraph 2, the rods are very sensitive to bluish light, whereas the cones have a sensitivity curve with 3 peaks (red, green and blue).

The combination of the higher total sensitivity of the rods for the blue range with the color perception through the cones results in a very strong appearance of bluish colors.

That is why the valid measurement of brightness perception is the photopic to scotopic ratio, instead of, until recently, only the photopic part: the ratio of scotopic (S) to photopic (P) output of the light source (=S/P) instead of only P.

4.2 Reduce eye fatigue and lens error

As we already stated, the rods are active at typical interior light levels. This property not only allows a better eye performance, it also permits reduction of visual fatigue.

The eyes automatically adapts in order to bring the viewed objects into focus. Adaptation, also called accommodation, requires the eye to do work by changing the shape of the lens in order to bring the desired light rays into focus.
If the pupil of the eye gets smaller, the net amount of accommodative work is also automatically reduced. Actually the muscle which is concerned is the iris: the iris lets the proper amount of light through the pupil and into the eye: it opens when there is little light and closes when there is a lot.

There are two ways of achieving a smaller pupil, that is to say to reduce the eye’s work and therefore eye fatigue:

- To increase light levels: this is not the most efficient way because the pupil size is predominantly controlled by signals from the rod receptors. Increasing the light, contrarily, means having only the cones activated.
- To have the rods activated, so as to have the highest possible S/P ratio, which is achieved at interior light levels.
- Furthermore, the iris reacts more to blue light and closes therefore better and faster: blue light has more effect on the iris. The “lens error” decreases if the pupil size decreases (the eye acts as a convergent lens). As a result, less lens error is achieved and so a sharper image is printed on the retina. Blue images not only have a higher contrast but also a higher sharpness.

5. Conclusion, summary

To have the ….

Optimal viewing conditions

Cones for details resolution

Rods for contrast resolution
For less eye fatigue
For fast/motion image adequate

Both sensors (rods and cones) have to be active

Rods & Cones are active

This happens

At interior light levels = best working conditions

The total sensitivity is then a function of the cones' sensitivity curve and the rods' sensitivity curve.

Because the

Rods are blue-sensitive, only

The highest total sensitivity is achieved when the eye is excited in the blue range.

The sensation of brightness is enhanced with the bluish light. Bluish pictures improve the efficiency of the viewing system, and the viewer's eye comfort (less eye strain)
This can be achieved with

Blue tinted backlight on Displays

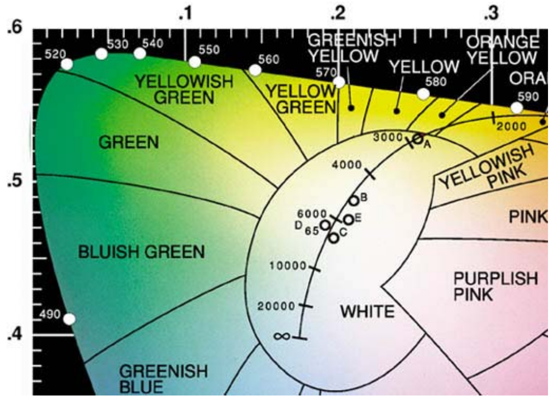


Fig. 5. how to achieve a "bluisher" white color.

Visual systems properties can be used in an optimized way :

- adapt the emission of your display system to work in the mesopic surrounding (dimmed environment)
- then your eyes will use both photosensors simultaneously which will provide
    - better contrast resolution (rods)
    - more detailed resolution (cones); and
    - more effective diagnostic ability

Siemens was the first to recognize the importance of the blue backlight feature for Medical diagnosis and to implement it in its LCD product line. Siemens Display Technologies continues to use this advantage to further define the best LCD technology for Radiology.

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