



Night Vision

The Red Myth

Unaided night vision even now in the 21st century is still the subject of some controversy.

For those just looking for an executive answer as to what supplemental lighting should be used to reduced the recovery time back to night vision (dark adapted or scotopic) here it is: a fully dimmable white light! This of course is a very incomplete answer but so are the answers red or blue-green and you should know why.

Lets start with red, specifically what I will call the red light myth.

I believe the myth started in the photographic darkroom.

Until about 1906 most photosensitive material (plate, film, and paper) was not very sensitive to red. Some of these orthochromatic materials are still used. This allowed these materials to be dealt with for a short time under a relative bright red light because the human eye can see red if the level is bright enough. The fact that L.E.D.s (having a number of advantages over other light sources) were economically only available in red for some time has also help to perpetuate this myth.

As more research about the eye was done it was found that the structure responsible for very low light vision, the rods, were also not very sensitive to red.

It was assumed then that like film you could use red light, which is seen by the red sensitive cones (there are also blue and green sensitive cones to give color vision), without affecting the rods.

It takes a while for true night vision to be recovered. About 10 minutes for 10%, 30-45 minutes for 80%, the rest may take hours, days, or a week. The issue is the chemical in the eye, rhodopsin - commonly called visual purple, is broken

down quickly by light. The main issue then is intensity; color is only an issue because the rods (responsible for night vision) are most sensitive at a particular color. That color is a blue-green (507nm) similar to traffic light green (which is this color for an entirely different reason). It would seem that using the lowest brightness (using this color) additional light needed for a task is the best bet to retain this dark adaptation because it allows rods to function at their best.

Unfortunately there are a number of drawbacks using only night vision.

Among these are:

- The inability to distinguish colors.
- No detail can be seen (about the same as 20/200 vision in daylight).
- That nothing can be seen directly in front of the eyes (no rods in the center of the retina), you must learn to look about 15-20° off center.
- Only motion can be detected well, therefore you may have to learn to move your eyes to detect something that doesn't move.
- Objects that aren't moving appear to move (autokinesis). This has probably led to a number of plane crashes.

If you need to see directly in front of you or see detail you need red. Like many myths the red light myth has some basis in fact. The red truth?

Why red? The center 1.5% of your retina (the fovea) which provides you with most detailed vision is packed almost exclusively with red sensitive cones.

This is the same area that has no rods and is responsible for the night blind spot. There are fewer total green sensitive cones than red. The number of blue sensitive cones is very small compared to green and red.

Which is just as well since the lens in the human eye cannot focus red and blue at the same time. And using green really only changes perceived brightness because of the way the signals are processed in our neural pathways. Unlike a digital

camera, more pixels, in this case, doesn't give us more detail.

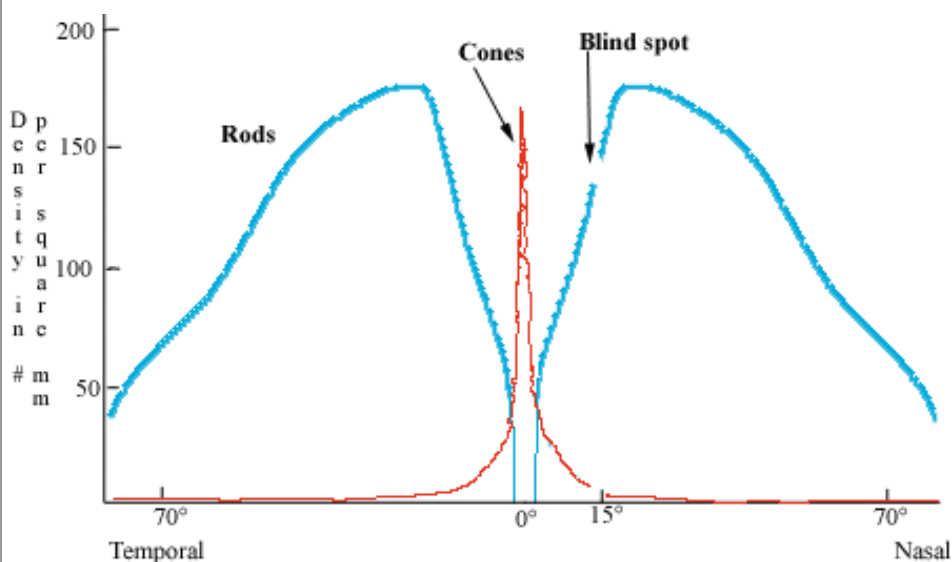


Chart showing the distribution of rods vs cones. Note the absence of rods in the center and the absence of both about 15° away from the the center toward the nose where the optic nerve passes.

At first glance the tendency would be to pick the hue of red at which we are most sensitive (566nm) which would make sense except for the real reason: we don't want to involve the rods. The reason is the rods share the neural pathways with the cones so that you have this fuzzy image overriding the detailed one. This effect disappears at slightly higher mesopic levels which is why white is a good choice for most tasks. Many people look at the numbers for sensitivity for rods and cones and forget that in most cases the numbers have been adjusted so that rod peak sensitive matches cone peak. Rods are in fact sensitive well into the infrared (not too useful except to know that light you can barely sense can adversely impact your night vision). The key then is finding a hue that we can have at a high enough intensity that we can see the detail we need without activating our rods to the point were they obscure that detail. Most source say this should be nothing shorter than 650nm. Experimentation shows a L.E.D. with a peak around 700nm seems to work best (perceived as a deep red). Note that red may be fatiguing to the eyes.

Conclusions:

- No matter what your color choice it must be fully adjustable

for intensity.

- If you need the fastest dark adaptation recovery and can adjust to the limitations, or everyone in your group is using night vision equipment then blue-green.
- If you must see detail (reading a star chart, or instrument settings) and can lose peripheral vision ([see note 1](#)), then a very long wavelength red at a very low level. Red really only has an advantage at very low levels (were the night blind spot is very obvious).
- A general walking around light so that you don't trip over the tripod, knock over equipment or bump into people, then blue-green with enough red added to get rid of the night blind spot, or maybe just use white. Blue-green at higher brightness also works very well and at a lower intensity than white.
- If you need to see color and detail then likely the best choice is the dimmest white light for the shortest amount of time.
- If you are in the military you must follow their rules; hopefully they will have a good course in unassisted night vision.
- If you are a pilot and say you only fly in the day, you should be aware of the problems of night vision and should consider a basic (ground) course in night flying.
- If you wonder why no one else has drawn these conclusions look at the dashboard of most cars. The markings are large, the pointers are large and an orange-red (a compromise, for certain "color blind" persons) and at night it is edge lit with blue-green filtered fully intensity adjustable light.

For Best night vision:

- Be sure you are getting enough vitamin A or its precursor beta-carotene in your diet (needed for the visual purple).
- Green leafy stuff is best followed by vegetables that have an orange color. Yes that includes carrots but spinach or dark leaf lettuce are better. It is possible to get too much vitamin A especially as a supplement.
- Keep up your general health. Smoking is also very bad for night vision, as are most illegal drugs and some prescription drugs.

- Keep you blood sugar level as even as possible. No meal skipping. Six small meals are better than three large meals. For carbohydrates favor starches (potatoes, rice, and bread) over simple sugars (sweets, alcohol).
- Use dark neutral gray sunglasses, that pass no more than 15% in full sun, when outside during the day.

True night blindness is rare. Most of what people call night blindness is either a lack of vitamin A in the diet or a failure to understand the night blind spot.

Cataracts, even minor ones, increase the effects of glare at night and the eye's lens does yellow and passes less light as we age which may contribute to what some call night blindness.

Note: The red filtered light at the intensity most people use is likely decreasing night vision much more than a properly dimmed white or blue-green light would!

Note: There are day blind spots also but are in a different position in each eye so are less of a problem.

Note: Blue-green (also called cyan, turquoise, teal and other names) as used here is NOT the combination of two colors but is a single particular hue. I use the most common name for that hue.

Mil-STD 1472F 5.8.2.2 (table XVI) display lighting

Condition of use	Lighting Technique *	Brightness of markings		Brightness Adjustment
		cd/m ²	foot-lamberts	
Indicator reading, dark adaptation necessary	Red flood, indirect, or both, with operator choice	0.07-0.35	(0.02-0.1)	Continuous throughout range

Indicator reading, dark adaptation not necessary but desirable
Red or low-color-temperature white flood, indirect, or both, with operator choice
0.07-3.5† (0.02-1.0)
Continuous throughout range

Indicator reading, dark adaptation not necessary
White flood
3.5-70 (1-20)
Fixed or continuous

Panel monitoring, dark adaptation necessary
Red edge lighting, red or white flood, or both, with operator choice
0.07-3.5 (0.02-1.0)
Continuous throughout range

Panel monitoring, dark adaptation not necessary
White flood
35-70 (10-20)
Fixed or continuous

Possible exposure to bright flashes,
White flood
35-70 (10-20)
Fixed

restricted
daylight

Chart reading, dark adaptation necessary	Red or white flood with operator choice	0.35-3.50 (0.1-1.0)	Continuous throughout range
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Chart reading, dark adaptation not necessary	White flood	17-70 (5-20)	Fixed or continuous
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* Where detection of ground vehicles or other protected assets by image intensifier night vision devices must be minimized, blue-green light (incandescent filament through a filter which passes only wave lengths shorter than 600 nm) should be used in lieu of red light.

† Possible error in original, read as: 0.07-0.35, likely occurred when converted to metric.

This is intended only as an overview, no warranty of this information is expressed or implied

[Update 17 Nov 2003] I find new myths are springing up. Such as blue-green L.E.D.s are emitting two colors of light. This is a mis-understanding of the color name and that this is the most accepted name for this one color. Another is that blue improves night vision. While at somewhat higher levels it, of course, is stimulating the rods. It is not an optimum color. Another long standing myth is that human visual perception is based on three colors when it is really based on four. The rods are usually

ignored because many people believe, wrongly, that at the brightness at which we perceive color the rods are no longer providing our brains with any information. In fact the perception of brightness is highly influenced by the rods well into the photopic (bright light) range of vision. Fluorescent lamp manufacturers have used this knowledge for a long time. "Cool White" lamps have an additional amount of green phosphor added to make us "see" them as being brighter! Of course the whole subject of color vision and the variances thereof (wrongly called "color blindness") will require a number of new pages even in synopsis form.

A point I forgot to cover is that to help preserve night vision in one eye the other may be closed or covered if you know your are about to be exposed to a brighter light, such as from a oncoming vehicle. For normal observation both eyes should be kept open. If it is difficult to concentrate on the desired image the eye not being used may be covered but not closed. Closing affects focus and possibly acuity.

[Update 14 Dec 2003] A very important point barely mentioned in the original is that human peripheral vision is almost completely rod based! The implication then is that we cannot see color at the edges of our vision. If you think we can, try this simple experiment. You will need a small assortment of color cards (try sheets of construction paper) and someone to assist you. Sit looking straight ahead while your assistant, about 6 to 10 feet away, slowly moves a random color card into the margin of your vision. Now, while still looking straight ahead, what color is is the card?

This is the second most important factor that has been ignored in the design of outdoor lighting, the first being glare! However this [study](#) (in pdf), at the U. S. Dept. of Transportation, is a subjective study of blue tinted headlamps.

[Update 23 Jan 2004] A few random notes to be better integrated into this document later.

Luminances are approximate and will vary with the individual and conditions.

Vision luminance range $1 * 10^{-6}$ to $1 * 10^6$ cd/M²

Rods luminance range $1 * 10^{-6}$ to $1 * 10^3$ cd/M² (may still play a roll above this range)

Cones luminance range $1 * 10^{-3}$ to $1 * 10^6$ cd/M²

Explain "Purkinje shift"

20/20 vision is the ability to resolve 1 minute of arc at 20 feet.

Discuss Ricco's Law.

Discuss afterimages.

Saw the yahoo search string: "Do color blind people have better night vision?", which is an interesting question. Those with the genetic factor shifting the L (red) cones toward green are accepted as usually having better twilight vision, however the only place I've seen a suggestion of improved night vision is in the Wikipedia!

References *(all external links open in new window - **Not responsible for the content of any outside links**)*

- ["Dark Adapted"](#) - a program for setting the gamma of your computer display to help preserve night vision (Win and Mac) and your choice of color
(note: price is right and better than just placing a filter over the screen, although the right filter (in addition) might help in special very low level work)
- [Light and Dark Adaptation](#) - Webvision - John Moran Eye Center - University of Utah
- [Vision and the Eye](#) - Physics Dept. University of Florida
- [The LED Museum](#) - Craig Johnson, host
- [An Adaptation Model](#) for Realistic Image Synthesis. by Ferwerda, Pattanaik, Shirley, Greenberg. SIGGRAPH '96 Conference
- [Simulation](#) of Human Visual Response at Varying Levels of Illumination (requires java, good simulation but does not show blind spot and loss of acuity is not as much as it should be)
- [Radiometry and photometry FAQ](#) - Optical Sciences Center - University of Arizona (.pdf Acrobat)

- [SCOTOPIC LUMINOUS EFFICIENCY FUNCTION OF THE HUMAN RETINA](#) from PROCESSES IN BIOLOGICAL VISION
- [Chapter 8 Principles and Problems of Vision in FM 3-04.301](#) - Aeromedical Training for Flight Personnel - U. S. Army
- [NIGHT VISION in MILITARY AVIATION](#) - USAF School of Aerospace Medicine
- [Mil-STD 1472F](#) DoD Design Criteria Standard - Human Engineering (.pdf Acrobat) [link changed 04/06/2004]
- [Human visual pigments](#): microspectrophotometric results from the eyes of seven persons. - Dartnall HJ, Bowmaker JK, Mollon JD. - National Institute of Health
- [Visual pigments](#) of rods and cones in a human retina - JK Bowmaker and HJ Dartnall - The Journal of Physiology
- [Tetrachromacy](#) of Human Vision: Spectral Channels and Primary Colors - Vitali V. Gavrik - Inter-Society Color Council (.doc word file)
- [Advances in Photoreception: Proceedings of a Symposium on Frontiers of Visual Science \(1990\)](#) especially "Photosensitivity of Primate Photoreceptors" which can be read online free at [Nat'l Academies Press](#) (note graph on page 34)
- [Basic data](#) (but all normalized to a peak value of 1) from Color & Vision database at the Institute of Ophthalmology in London

Pages referencing this:

- [Gammatron](#)
- from time to time on [CandlePower Forums](#) such as [this thread](#).
- mentioned on a German [astronomy forum](#)
- mentioned on [The Astronomy Connection mailing list](#)
- mentioned on [Astronomy 201 Course from February 2004](#)
- mentioned on [CouldyNight's astronomy forum](#) and [this thread](#) as well.
- mentioned on [Pontchartrain Astronomy Society's astronomy forum](#)
- a link from the [BMW E28 Enthusiasts Forum](#)
- and as part of the [Charleston Fishing forum](#)