

The Effects of Blue Light on Ocular Health

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Why should we care about blue light?

For years now, professionals in the fields of light energy and vision have known about the hazards ultraviolet (UV) light presents to ocular health. We are gradually having longer and more intense exposures to blue light; much of the world of commercial display and industry is lit with cool white fluorescent tubes which emit a strong spike of light in the blue range. Indeed many homes and offices are lit with cool white fluorescent tubes. No one doubts more people are spending time in front of video display terminals (VDTs) which produce blue light. While some people find blue light irritates their eyes or causes headache, most are able to ignore it. Scientists only now are beginning to investigate its long-term effects and offer some solutions for maintaining ocular health in the presence of blue light.

What is blue light?

Experts differ as to the exact wavelength of UV light waves, but generally speaking, UV light is defined as that part of the invisible spectrum which ranges from 380nm to 200nm. (Nm stands for nanometer which is one billionth of a meter.) This part of the spectrum is divided into UV-A, (380nm to 315nm), UV-B, (314nm to 280nm,) and UV-C (279 to 200nm.)

UV-C, the shortest wavelength for purposes of this report, is virtually absent from ordinary lamps, blacklight and sunlight within the earth's atmosphere. It is largely germicidal in nature and is used by dentists and in industry for sterilization purposes. One of the primary benefits of the ozone layer is that it filters out virtually all of UV-C. However, UV-B and UV-A do manage to enter our atmosphere where UV-B and to some degree UV-A, have been implicated in the formation of skin cancers and cataracts and in the degeneration of retinal tissue. (Van der Leun and Gruijl, 1993). UV-A is particularly plentiful in the light emitted from black light bulbs, so popular in "sensory stimulation" activities. However, until recently, little was said about near UV, or "blue light" and its effects upon the eye. Blue light is that light with wavelengths in the 500nm to 381nm range. Both blue light and UV-A are sometimes referred to as "near UV," but for purposes of this report, "near UV" refers to blue light.

What about "black light?"

Of special concern is the blue light given off by "black light" tubes and bulbs. These are glass tubes/bulbs coated with special phosphors on the inside surface. When the gas in the tube is excited by an electrical current, it glows; when the light passes through the coated glass, only the wavelengths in the UV-A and blue light range are emitted. When viewed under black light, many objects fluoresce. This fluorescence is deemed desirable by party-goers, artists and even educators.

In 1980 the team of Poland and Doebler used black light to test eye-contact training with children who had cerebral palsy. They found their subjects performed

better under black light than under ordinary room light. In 1983 these findings were again supported by Potenski in a similar experiment with multiply handicapped, deaf-blind children. The conclusion was that severely brain-damaged children seemed better able to use their vision when only the task was highlighted and the rest of the environment lay in darkness. Neither study remarked about any safeguards employed to protect the practitioner or the students from the effects of UV-A or blue light emitted by the black-light tube. Further, neither study employed a control group which performed the same tasks in a dark room under an ordinary spot lamp, for comparison.

Review of Literature

Retinal Damage

In an early study conducted by Ham, Ruffolo, Mueller and Guerry, (1980) rhesus monkeys were exposed to high-intensity blue light at 441nm for a duration of 1000 seconds. Two days later lesions were formed in the retinal pigmented epithelium (RPE.) These lesions consisted of an "inflammatory reaction accompanied with clumping of melanosomes and some macrophage invasion with engulfment of melanosomes which produce hypopigmentation of the RPE" (Ham et al., 1980, p.1110). Since melanin, a common pigment component present in the RPE, strongly absorbs blue light, there is reason to be concerned that the retina is subject to actinic injury from blue light.

However, the lens strongly absorbs blue light as well but runs a high risk of possible opacification.

Human studies have not been conducted due to the obvious ethical problems involved in deliberately subjecting humans to potentially hazardous conditions. However, Taylor et al., found an association between cataract formation and exposure to UV-B when he studied 838 watermen who worked on Chesapeake Bay. He was not, however looking for a link between near UV and retinal or lens cell anomaly. The closest studies available are ones which use animals. Among researchers and scientists who have studied blue light, many are of the opinion that blue light might be a hazard and precautions would be wise. Some researchers are more certain: Ham et al., after conducting studies on animals, suggested "long term, chronic exposure to short wavelength light is a strong contributing factor to senile macular degeneration" (p. 1110).

In 1992, Chen, a researcher at St. Erik's Eye Hospital in Sweden, sought to explore the basis to explain why blue light reactions cause retinal degeneration. Drawing on the research of E. L. Paulter, Morika and Beenley (1989), who found that a chemical chemical called cytochrome oxidase is a key enzyme in the respiration of the retina in higher mammals, Chen decided to investigate this phenomenon in rats. Cytochrome oxidase is found in the RPE and in the inner segment of the photoreceptors. Paulter's in vitro studies of bovine REP tissue showed that blue-light exposure destroyed cytochrome oxidase and inhibited cellular respiration. This inhibition was followed by retinal degeneration. Chen then performed a similar experiment upon rats in which he exposed them to 15 minutes of 404nm blue light which was not strong enough to cause thermal damage. He then killed some rats immediately, and one for

each of the next three days. Upon examining their retinas, he found the blue light exposure had indeed inhibited the production of cytochrome oxidase. This was evident in his observation of the photoreceptor cells which had been destroyed. He concluded

inhibition of cytochrome oxidase by blue-light exposure and the consequent suppression of the cellular metabolism is a potential cause of retinal degeneration (1993, p. 422).

One might argue that results in laboratory rats are not necessarily indicative of human results. For this reason, primate research often follows other mammalian research. In 1980 the group of Sperling, Johnson and Harwerth irradiated the retinas of baboons and rhesus monkeys with blue light. The eye tissues of these primates are very similar to those of humans. In addition to color blindness in the blue-to-green range, Sperling et al. found

extensive damage in the RPE resulting from absorption of energy by the melanin granules. It should be pointed out that the damage seen . . . including macrophagic activity, disrupted cells and plaque formation, is characteristic of that seen by Ham et al. (1978), and others in what he calls the photochemical lesion.

In light of findings like these, ophthalmologists are beginning to filter the blue light emitted from their ophthalmoscopes through a yellow lens. A study by Bradnam, Montgomery, Moseley and Dutton concluded: "This study has shown that the use of a yellow lens is very effective at reducing the blue-light hazard and extends the safe operating period by a factor of approximately 20x. . . In the interests of patient safety, it

is recommended that yellow lenses are considered for use for routine indirect ophthalmoscopy" (1994, p. 799).

Lens Damage

After some yellowing, by the age of 20, the lens becomes a natural, though imperfect, absorber of wavelengths between 400 and 320nm. It helps protect the retina from damage by near UV radiation. The lens also provides partial but imperfect protection to the retina from blue light. In early studies it was thought that UV-B was the only wavelength band responsible for cataracts. However

Most authorities now believe that the near UV radiation absorbed throughout life by the lens is a contributing factor to aging and senile cataract. Thus, by protecting the retina from near UV radiation, the lens may become cataractous. My own personal opinion is that both the retina and the lens should be protected throughout life from both blue light and near UV radiation. This would delay the onset of senescence in both lens and retina (senile cataract and senile macular degeneration.) (Ham, 1983, p. 101).

Youths under the age of 20, and especially very young children, have little or no yellowing of the lens. Therefore any UV or blue light which enters the eye is unfiltered and strikes the retina at full-strength exposing not only the retina, but the lens to damage.

Nancy Quinn, a registered nurse and an expert on blue light emissions from VDTs wrote:

Blue light wavelengths and part of the blue spectrum are focused in front of the retina, while green and yellow are focused on the retina, and some red spectrum is focused behind. Thus blue light contributes little to visual acuity and visual perception loses sharpness as the blue light component adds significantly to the eye's energy expenditure for focusing, and if reduced can greatly reduce eyestrain without loss of acuity.

There is mounting medical evidence that prolonged exposure to blue light may permanently damage the eyes, contribute to the formation of cataracts and to the destruction of cells in the center of the retina (n.d.).

What can be done?

Ham et al. (1980) and Gorgels and van Norren (1995) pointed out that actinic, or photochemical damage to retinal tissue, is more a function of wavelength than either intensity or duration. Gorgels and van Norren, after examining rat retinas damaged by blue light, wrote "duration had no influence on damage threshold dose, nor on morphology. We conclude that wavelength (and neither irradiance nor duration) is the factor responsible for the encountered morphological differences"(p.859).

These studies suggest neither the human cornea nor lens provides sufficient protection from blue light for our modern environment. Our ancestors did not have to deal with many hours under cool white fluorescent light, nor did they spend any time looking at video display terminals at close range. Our eyes' natural filters do not provide sufficient protection from the sunlight, let alone blue light emitted by these devices nor from the blue light emitted from black-light tubes.

As a feature of their molecular structure, many plastics have the ability to filter out UV-A and UV-B light. Clear polycarbonate spectacles are now available which are labeled "filters 100% UV." Clear plastic, however, will not filter out blue light. In order to accomplish this, the filter must be tinted. Yellow is the preferred color because it allows the best contrast for the most people while still offering UV and blue light protection. Bradnam, et.al. (1994) showed the yellow lens to be very effective in protecting the retinas of their patients who were being exposed to blue light during ophthalmoscopy. In the case of black light activities, yellow is the only color which gives adequate blue light and UV protection, under which fluorescent materials will still appear to fluoresce. Both Solar Shield and NoIR produce a yellow lens which filters out 100% UV and 100% blue light. Filters should always be between the light source and the eyes. For this reason, visors or spectacles work best. Acetate sheets, which are often used, offer little or no protection from blue light.

The blue light factor should be of maximum importance to persons working with young children *and* with individuals who may have albinism, aphakia, achromatopsia, coloboma, sub-luxated lenses and other conditions in which the light reaching the retina is unfiltered, or causes extreme light sensitivity. Professionals in the field of vision would profit by, at the very least, employing proper filtering precautions and limits of exposure to both subject and practitioner, when using black light and other sources of blue light during sensory stimulation, and visual training activities.

Practical Suggestions

1. Student and practitioner should always wear yellow-tinted lenses or visors which offer 95-100% UV and blue light protection during the use of black light.
2. Black light usage should be very limited. Recent studies suggest that the old guidelines of 2-3 times per week per child with sessions less than 15 minutes each (Moore, 1986) may be too much. Efforts should be made to wean the student from black light into dim light and then into daylight vision development activities.
3. UV screen filters which fit over the display terminal, or UV filtering spectacles should be worn during the use of a video display terminal (computer screen.)
4. If possible, limit the use of cool white fluorescent tubes, full-spectrum lights, daylight tubes or bulbs, or mercury lights in the environment. **Substitute warm white tubes or incandescent lamps if possible.**
5. Students or practitioners with albinism, aphakia, coloboma, sub-luxated lenses or achromatopsia should wear UV/blue filtering lenses or visors outdoors and also indoors if under cool white fluorescent or mercury lights.
6. Always make sure the source of blue light is below waist level, or behind the student. Blue light sources should not be near eye level.

These few simple precautions may help to preserve the ocular health and comfort of students, rehabilitation clients, and the professionals and paraprofessionals who serve them.

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