Chemistry explains why you shouldn’t stare at the solar eclipse without protection

Looking at the sun can set off damaging radical reactions in the eye

By Tien Nguyen

On Aug. 21, millions of people across North America will watch a solar eclipse with wonder and, hopefully, protective eyewear.

Solar eclipses have long come with warnings about the dangers of looking up and staring at the sun. The Greek philosopher Socrates is said to have told Plato in 399 B.C., “People may injure their bodily eye by observing and gazing on the sun during an eclipse.”

Despite the age-old wisdom, in the days after these dazzling events, doctors still report cases of blurry vision or even blind spots caused by peering at the sun. The injuries incurred are actually the same as when people stare at the sun on a normal day; the difference is people are particularly tempted to look up during an eclipse.

Normally, glancing at the sun isn’t much more than a “nuisance,” says Dirk van Norren, a retired professor of ophthalmic physics at the University Medical Center Utrecht. “But if you glance over an hour or so, it adds up,” he says. “That’s the whole danger of an eclipse.”

Van Norren estimates that it takes about 20 or 30 glances, adding up to approximately half a minute of staring, before an adult would get injured. Though skipping the proper precautions is a bad idea, most eclipse-related injuries are minor, he says, “because frankly, you’d have to be quite an idiot to stare so long into the sun.”

**So how does the sun inflict its ocular harm?**

People once assumed that sun-related eye damage was caused by heat, imagining that a human lens acted like a magnifying glass on a sunny day to burn the eye’s retina. This idea was widely accepted until 1962, when a physicist named Johannes J. Vos—who is now a professor emeritus at TNO Human Factors and happens to be van Norren’s first boss—proved that the hypothesis was wrong.

Staring at the sun can derail healthy chemical pathways, causing blurred vision or even blind spots.

In the seminal study, Vos calculated the local temperature change in the retina when exposed to direct sunlight. He found that given the dilation of a normal eye, which is about 2 mm in bright light, the sun’s energy could cause only a 2 °C temperature rise, or about the same as a mild fever, van Norren says. The local temperature increase would have to be at least 10 °C to damage the eye by cooking its proteins like scrambling an egg.

After ruling out heat as the source of the damage, Vos hypothesized that so-called metabolic poisoning was the culprit. He defined this phenomenon as the accumulation of waste products from biochemical processes in cells.

Four years later, Werner K. Noell, who was a physiology professor at the University at Buffalo, demonstrated that Vos was onto something. Noell’s team exposed albino rats to low-energy fluorescent lights over an extended period of time. Because the light lacked enough energy to heat up the animals’ tissues, the team determined that the resulting retinal damage was photochemical, not thermal.

Once the photochemical nature of light-induced damage became known, researchers focused on figuring out the damage “action spectrum,” meaning the range of wavelengths in sunlight that cause harm.

The eye’s excellent natural defenses automatically filter out some wavelengths. The eye’s outermost layer, known as the cornea, catches the short-wavelength region of ultraviolet-B light while the lens, the eye’s window, filters out the remaining UV-B and part of the UV-A range. The lenses in young children’s eyes are clearer than those in adults, which makes children more susceptible to overexposure to sunlight. On the other end of the light spectrum, long-wavelength infrared light gets absorbed by the watery goo in the eye. That leaves wavelengths between 400 and 1,400 nm to worry about in terms of damage.

In Noell’s albino rat study, the researchers proposed an action spectrum that peaked around 500 nm—green light. This spectrum overlaps squarely with the absorption spectrum of rhodopsin, the photoreceptor protein found in the eye’s rod cells that helps you see in low light. But over the next 50 years, only a weak study could replicate Noell’s findings, according to van Norren.

Eventually, the field agreed on an action spectrum that peaked in the blue light range. Still, scientists don’t completely understand the mechanism of photochemical damage. They suspect that it can be traced back to one compound.

Malgorzata Rozanowska, a senior lecturer in the School of Optometry & Vision Sciences at Cardiff University, says, “There’s a lot of evidence pointing to all-trans-retinal as the culprit.”

All-trans-retinal is a substituted cyclohexene compound with a long aldehyde-capped side chain that’s key to vision. In the eye’s rod and cone cells, photoreceptor proteins contain the molecule 11-cis-retinal. When light hits these proteins, it catalyzes the isomerization of 11-cis-retinal to all-trans-retinal, which then triggers a chain of cellular events that lead to the production of an electrical signal. This process is how these photoreceptor proteins “communicate to neighboring neurons that the photon has been absorbed,” Rozanowska says.

Normally enzymes in the eye reduce all-trans-retinal to form the corresponding alcohol, all-trans-retinol, known commonly as vitamin A, which reacts further to eventually regenerate 11-cis-retinal and then reform rhodopsin.

If too much light overwhelms the system—for example, when a person looks too long at an eclipse, levels of all-trans-retinal can build up, and the molecules start to absorb light energy directly. This absorption kicks one of all-trans-retinal’s electrons up to a short-lived excited singlet state. From there the singlet state can undergo a process called intersystem crossing to form a longer-lived triplet state. In this state, all-trans-retinal can react with oxygen to form various reactive oxygen species, such as hydroxyl radicals, to set off a cascade of damaging free radical reactions.

The reactive oxygen species readily oxidize important compounds in the eye, including proteins and unsaturated fatty acids such as docosahexaenoate, which are abundant and help transport nutrients and chemical messages in the retina.

**That’s when things get bad.**

Rozanowska explains that although one excited all-trans-retinal molecule generates one molecule of a reactive oxygen species, once that species reacts with a fatty acid in a lipid, it sets off a chain reaction that can lead to hundreds of lipids getting oxidized. These compounds then become more rigid and worse at transporting nutrients in cells. Unchecked oxidation can lead to cell death and retina damage.

Some data suggest that antioxidants in our diet can prevent these damaging reactions, but Rozanowska says that when it comes to dodging light-induced eye damage, “the best protection is prevention.”

Though hard to resist during a solar eclipse, she suggests avoiding gazing at the sun without the proper protection, such as special eclipse-viewing glasses. Another strategy is to face away from the eclipse and view it with a pinhole projector. This simple construction requires just two sheets of paper: one with a tiny hole for light to pass through and one to project the eclipse’s image onto.

People have also been known to view the eclipse through sooted glass, which is made by holding a candle beneath the glass and letting soot accumulate on the surface, van Norren says. He doesn’t recommend this option because it’s too easy to accidentally wipe the soot off the glass.

Other materials that prevent an unhealthy amount of light from getting to your eyes can be used to watch an eclipse. A few years ago, van Norren viewed a partial eclipse in Europe through the plastic of an audio compact disc. He suggests that old camera film may work as well, though quality may vary.

A simple rule to keep in mind, he says, especially when buying eclipse-viewing glasses online, is that you should be able to stare comfortably at the sun through the material. If you can’t, then the material doesn’t make the cut. That means regular sunglasses are not sufficient to ensure safe viewing. Proper eclipse glasses should carry a label indicating that it meets the ISO 12312-2 international safety standard by blocking more than 99.99% of the sun’s light.

Van Norren, who has spent his career dedicated to vision research, offered this final piece of advice for viewing the solar eclipse: Enjoy it.

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