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Guest Editorial

Some afterthoughts about eclipse blindness

The sun eclipse that kept Europe spellbound in the summer of 1999 produced a true tide of 'expert' views in the media on eye protection. Viewing via sooted glass—the main protective measure since times immemorial—was pronounced absolutely unsafe; viewing through a CD—a more trendy variant—was equally condemned. Only officially approved (by whom?) eclipse goggles (often printed with 'do not use after 11 August 1999'!) should be considered safe; do not use fake goggles, since they transmit UV; and so on. The chief medical advisor of the British government, Liam Donaldson, even declared that viewing the eclipse was dangerous under any circumstances. A common characteristic of all these 'expert' views was a virtually complete absence of valid arguments. No wonder: the media like strong views to be expressed rather than balanced arguments, and eclipses are so infrequent that few can claim actual expertise. This contribution is intended to fill that gap and to tentatively provide a scientific basis for those who will be called to give advice at future similar happenings.

First of all: what causes eclipse blindness? For a long time a retinal burn was, understandably, thought to be the culprit because of the easily appealing parallel to the way a converging lens can burn a hole. There are strong arguments, however, that retinal burn is not the cause. Firstly, thermal calculations show that the temperature rise in the solar image at the retina[1] does not exceed 2°C with a normal fully contracted pupil; just a mild local fever (Vos, 1962; White *et al*., 1971). Moreover, this 2°C is reached within a few tenths of a second, whereas lasting retinal damage due to looking into the sun seems to require a period of some half a minute (see later). Thus, neither the temperature rise, nor the time scale points to retinal burn as a cause. Moreover, since all of us now and then look at the sun for a few tenths of a second, should we not all be blind? Fortunately nowadays we have a good alternative explanation: light damage, a photochemical destruction of the retina, first described by Noell *et al*. (1966) and later in primates by Ham *et al*. (1976). The main difference with thermal damage is its accumulation over time. Heat is rapidly drained away from the retina, by conduction in the surrounding tissue and subsequent convection by the blood stream; hence, the moderate temperature rise and the short rise time. Photochemical damage, however, requires repair processes which are known to take days. Since viewing an eclipse from first to last contact takes about 2.5 h, the photochemical damage due to viewing the eclipsing sun for a series of brief periods can be considered to be fully cumulative. When, for instance, Headon *et al*. (1986) write that their eclipse patients had only stared for a few seconds into the sun, we may have our doubts. Fifty glances of a few seconds each will accumulate to a total exposure of several minutes! Similarly, two of Gladstone and Tasman's (1978) sunbathers admitted to frequent checking of the sun's position.

In ophthalmology light damage has become known as a real threat to the retina during surgery, due to over-exposure to the light from the operating microscope (McDonald and Irvine, 1983; Khwarg *et al*., 1987). The luminance of the field the patient looks into (10^7 cd/m^2) may be considerably lower than that of the sun (10^9 cd/m^2), but the dilated pupil largely makes up for that (factor $[8/2]^2 = 16$). As a result, an 8-min exposure to the unattenuated and unfiltered operating microscope light can indeed produce threshold retinal damage (Kremers and Van Norren, 1988), equal to that caused by a half-minute exposure to the sun, as one can calculate from the solar spectrum and the action spectrum[2] (Health Council of the Netherlands, 1993). That action spectrum peaks in the blue. Hence its nickname: blue light damage. Sensitivity for blue light damage rapidly reduces in the near UV due to absorption in the crystalline lens, and also in the longer wavelength parts of the visual spectrum, where the low energy photons are incapable of producing photochemical damage. This means that neither the infrared, nor the ultraviolet contribute much to eclipse blindness.

If we take half-a-minute as the critical exposure time to produce retinal damage for normal unprotected eyes, i.e. non-

[1]This calculation does not apply to viewing through a magnifier; a larger retinal image will lead to a higher retinal temperature due to diminished conduction of heat to the surrounding tissue.

[2]Note that the conventional safe exposure level lies a factor 33 below this threshold. Incorporating that factor brings the safe exposure time down to about 1 s.

aphakic and with non-dilated pupils, either by medication or by drugs abuse, protection during e.g. 1 h sun gazing may be obtained by reducing the exposure level to [30 s/1 h] $\approx 1\%$. Interestingly, this value is not far off from that of Socrates' (Plato, c. 490 BC) advice to rather look at the reflected image of the sun in water. Water, with a refractive index of 1.33, has a reflectivity at normal incidence of $[(1.33 - 1)/(1.33 + 1)]^2 = 2\%$. So an optical density OD = 2 filter (i.e. attenuating by two log units) should suffice; i.e. *to protect* the retina of the average adult who is viewing an eclipse in a 'normal' way, i.e. not exceeding a cumulative exposure time of 1 h. The restriction to *protection* is important, as looking at the only 100 times attenuated solar disc is still far from comfortable. Let us therefore approach the problem now from the comfort side.

The sun, we saw, shines with 10^9 cd/m^2 zenith value; with an apparent size of 0.5° diameter this produces a luminance of about 10^5 cd/m^2 for the pages of a book we want to read. Generally we do not like to read a book in the full sun. We then start screwing up our eyes and reaching for sun glasses. Let us therefore consider 10^4 cd/m^2 as an upper limit for comfortable viewing. That means that comfortable viewing requires a factor $(10^9/10^4) = 10^5$ light reduction. Thus, for comfort we need OD = 5, rather than the minimum of OD = 2 we thought necessary for safety. The value OD = 5 is in accord with the advice of most experts and also with an almost casual remark in the European standard for personal eye protection (European Standard 172, 1995). With infrared and ultraviolet discarded as damaging agents, comfort seems therefore the main proper criterion for the choice of an OD = 5 protective filter.[3] That makes things easy, since we do not need expensive instruments to check spectral transmission. We may just judge ourselves, and take a look, knowing that a very short glance, even with the unprotected eye, does not produce damage. Of course we realize that it will be many years before the next total eclipse occurs in Europe (actually: 29 March 2006 in Russia), but they occur once every 1–2 years somewhere on earth. We should also remember that equally risky partial eclipses are much more frequent. So, we attempt to formulate some advice for consumers and their optometrists.

First, there are the marketed eclipse goggles. They claim to have OD $\geq$ 5, just what we need. The story goes that less reliable 'fake' goggles were also marketed. No problem: check yourself by briefly looking at the sun. Silver coated CDs have also been recommended. There are a few problems, though: one is that they are marketed with various types of coating. The minimum value we found was only OD = 3, sufficient for eye protection, but insufficient for comfortable viewing. Then, there are commercial welding glasses, available in various shades. Shade 14 is sufficiently dark, as it complies with the requirement OD > 5. Finally, there is the classic do it yourself sooted glass solution, a solution which, in our opinion has undeservedly received such negative comments, probably only because the soot is vulnerable when handled. An interesting bonus of this solution, though, is that the hand made filter is *not* homogeneous. This allows scanning for the most satisfying spot when observation circumstances change, for instance with intervening cloudiness. With an OD = 5 eclipse goggle by contrast one might be tempted to switch dangerously to naked eye viewing when the sun gets clouded.

Can we be sure that the above given advice is safe? Let us be honest: liability claims have frightened most experts in the media, and the fear is understandable that people might misread 'a single glance' as 'just for a while' and interpret 'looking through a CD' as 'looking through the central hole'! And of course, patients with ocular pathology, including pseudophakes and monocular individuals, would be wise to be more careful than the normally sighted. But should that imply that we should not be correctly informative in a professional journal?

It is improbable, of course, that judges will accept a reference to Socrates as decisive. Moreover, Yannuzzi *et al*. (1989) presented case reports of solar (?) retinopathy which occurred without even looking at the sun at all. If true, these cases would undermine all laboratory studies on solar retinopathy. We have our doubts about the subjects' denials of looking at the sun, though. First, they may have had good reasons for their denials, for fear of losing insurance rights. But then, all four cases reported occurred in the New York area on an extremely sunny Good Friday, when we can be sure that many thousands must have sunbathed without suffering solar retinitis. So, the proper question to be asked is why only four experienced problems! As a matter of fact, Yannuzzi (private communication) admitted that "our cases could represent oddballs who stared at the sun against all warnings".

A similar argument can be applied with respect to the virtual absence of case histories after the 1999 eclipse in Western and Middle Europe. Of the millions who viewed the total or partial eclipse, only very few seem to have experienced real eye trouble. When so many have *not* experienced eye trouble, it seems reasonable to conclude that the warnings have worked and that the protection, either by eclipse goggles, by CDs, by hand made sooted glass or by what-ever means, has been quite adequate. Those unhappy few, one may surmise, have been those who have disregarded all advised protective measures.

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[3]Taking into account the formal safety factor and realizing that children have a higher transmission of the ocular media, are additional arguments.

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