As the world’s population ages, cataract-induced visual dysfunction and blindness is on the increase. This is a significant global problem. The most common symptoms of cataracts are ga...
Age related modifications of ß-crystallin induce alterations in lens crystallin interactions, which can be responsible for the increase in light scattering in old and cataractous lenses [18–21]. Alterations include both changes in the secondary structure and in the state of aggregation [22,23]. They are triggered by lens cells exposition to elevated temperatures or other stress factors such as UV light or Cosmic radiation (e.g. it has been shown an increase of the risk of nuclear cataract in airline pilots [24]), which disrupt the liquid-like molecular order and promote the formation of large scattering particles [25–27].

Fig. 1: Sketch of the experimental setup (top) and technical draw of the eye cell model (bottom).

Quite remarkably, temperature is a very simple way to reproduce many of the age-related lens changes. Simply exposing lenses to heat can replicate many changes that take place to the lens during our lifetimes, such as stiffness, loss of ß-crystalline, membrane fluidity, binding of proteins to cell membranes and decomposition of membrane phospholipids. Time and temperature are linked variables. It has been shown that short-term exposure to 50°C in the laboratory can reasonably be used to study processes in an experimental period that in the normal eye may take decades at 35–42°C [28].

Given the rapidity with which major lens changes can be induced under laboratory conditions at 50°C, it would not be surprising if such variation in ocular temperature could indeed modulate the rate of change of protein denaturation in the lens.

This same denaturation process occurs to albumen when an egg is boiled. In the past, albumen have been used as phantom for the study of tissue response and photocoagulation induced by laser light [29,30]. In fact, it has a well-known behavior of protein denaturation as function of temperature and time, which is related to its scattering and adsorbing properties [31–33].

Here, we use egg albumen as realistic phantom material in order to reproduce the changes of visual impairment due to aging in very good analogy with the protein denaturation that occurs in the eye lens. We built a cell formed by a sealed box with transparent walls, one being a plano-convex lens and the other a glass microscope slide. The cell is filled with albumen through two small perfusion holes placed on top. On the inside, furthermore, a thin tungsten wire connected to a voltage generator provides heating by Joule effect. A LED lamp is used to illuminate a slide and form the image. To obtain homogenous illumination, a diffuser was placed between the slide and the lamp. Finally, a camera is placed in correspondence of the image plane of the eye cell (see Fig. 1).

![Contrast behavior as function of time for different dilutions: 4:1 (red), 2:1 (green), 4:3 (gray), 1:1 (yellow), 1:2 (blue).](image)

In order to reproduce the progressive effect of protein accumulation at the center of the crystalline in aging subjects, some arrangements must be made. In fact, to obtain sufficiently sharp images the albumen should be diluted to reduce the light scattering at room temperature. On the other hand, if it is diluted too much the effect of protein denaturation could become negligible. We have tested different albumen/water dilutions: 4:1, 2:1, 4:3, 1:1, and 1:2. To quantify the effect of scattering due to protein denaturation on the image quality, we used a test slide with a line pattern on it (2.5 lm/mm). For each dilution, we evaluated the image contrast as the standard deviation of the intensity, calculated on the area correspondent to the pattern (see Fig. 2). The working voltage was fixed at 1V.

Taking into account the time-behavior of contrast and image sharpness at initial stage of the measurements, the plot in Figure 2 shows a better compromise for dilution 1:1. Using these value of dilution, we simulated the cataract-like degradation of image quality using a real-life scenario (Figures 3, Visualization 1). As time passes, proteins start denaturing and accumulating in correspondence of the center of the eye cell. In figure 3c, the image shows at first a slight increase of contrast (+7%) with a concurrent loss of brightness (-4%). The image quality, then, keeps on worsening until the amount of denatured proteins fills the center of the cell and scattering is so strong that light does not reach the camera anymore.

Cataract induces also an alteration of color perception. The images formed by the sufferers eyes result dimmer and yellowed. This is due to scattering of light inside the crystalline, which is more severe for smaller wavelengths. This deviates blue light more the red one, producing thus, a notable image yellowing. We have quantified color balance comparing the intensities of the three color channels of the camera, see Fig.3.
The image shows a photograph slide taken using only water. Images of the slide taken using a 1:1 albumen/water dilution show a gradual and sequential appearance of such features that mimic well the steady and relentless effect of aging upon vision, making it suitable as a tool for the assessment and illustration of age-related evolution in vision impairment caused by cataracts.

**Supplementary material.** See Supplementary 1 for supporting content.

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