Basic biophysical principles of the eye, such as the retinal projection of the visual field, bidimensional image inversion, blind point determination, visual field and retinal quadrants, perimetric principles, and determination of scotoma, are seen on a working anatomic model of the eye and its visual field that can easily be constructed at very low cost and from easily obtained materials: an opaque glass globe, a styrofoam hemisphere, a wood screen, bulbs, sockets, wire, and switches. This model has been used for many years in our undergraduate medical physiology courses and has replaced the classical model of candle image inversion by a converging lens.

Key words: eye model; image inversion; perimetric examination; physiology teaching

Undergraduate students of medical physiology are conventionally introduced to the physiology of vision with the inverted image of a candle projected by a thin converging lens on a white screen or with the use of the simile between the eye and a photographic camera. This is generally presented to the students as a drawing, a poster, or a slide. The most important contributions of these models are to give insight into the concept of focal distance, the unidimensional up-down inversion of the images from the visual field on the retina, and the idea that the converging lens is the only optic mechanism to produce such an effect. Important physiological concepts with clinical relevance, such as visual field and its relationship to retinal quadrants, visual perimetric examination, marginal vision, blind point, scotoma, and the camera obscura effect, many of which are also considered classical concepts (2), are ruled out by these models. Some commercially available computer software programs incorporate an atlas of anatomy and physiology of the eye that include animation techniques for light lines and image size (9, 10). These software programs are good for general educational purposes but are insufficient for medical physiology teaching. Other types of computer simulation are directed to specialized ophthalmologic education (1, 4, 6, 7). There are some eye models that have been proposed for ophthalmology education with the aim of giving students and residents a learning model for ophthalmoscopy, fundus photography, and therapeutic techniques such as photocoagulation (3, 5). Design and construction of an interesting eye model was described by Rudnicka et al. (8), which incorporated an autorefractometer to investigate the size relationship between a retinal feature and its photographic image.

An anatomic model of the eye that allows demonstration of visual field and fulfills the criteria described above can easily be constructed using the following materials: an opaque (or white) glass lamp globe; a styrofoam hemisphere similar to those used in flower decoration; two 35 X 35 X 0.3-cm wood screens painted white; and five small 115-V, 15-W bulbs with their sockets, wire, and five monopolar 115-V switches. The opaque (or white) glass lamp globe and the white styrofoam hemisphere are used in the model as the retina and the sclera, respectively (Fig. 1A); they fit into each other to give the effect of a coronal hemidissected eye where the anterior part forms the sclera, iris, and pupilar opening (Fig. 1A); they fit into each other to give the effect of a coronal hemidissected eye where the anterior part forms the sclera, iris, and pupilar opening (Fig. 1B) while the retina is exposed on the posterior part (Fig. 1C). The size of these elements must be large enough to allow...
FIG. 1.
Analog of visual field retinal projection. A: lateral view of entire model showing eye model (glass globe and styrofoam hemisphere) and visual field model (board with bulbs). B: frontal view of eye model showing styrofoam emulation of sclera, dark-painted iris, and pupillary aperture. C: rear view of eye model showing free surface of opaque glass globe simulating retina with retinal quadrants illustrated. Outermost circle represents remaining sclera, and space between circles represents coroides. Solid circle represents location of blind point (right eye) where a piece of cardboard is used to avoid retinal images. D: front view of the bulbs on the wood screen with representation of visual field quadrants. E: free-moving bulb/pencil stick used for perimetric study. Line connector of the handling tube is also illustrated.
all students to see the bulb projection on the simulated retina. A globe with a diameter of 24 cm and a slightly larger styrofoam hemisphere have been shown to be large enough for a demonstration for 35 students; however, these sizes can be changed in each case. After darkening the inner side of the styrofoam hemisphere with matte black paint for better contrast of the images, a 6 mm in diameter hole is made at the middle of the styrofoam hemisphere, this aperture represents the pupil of the eye and acts as a coarse form of a 'pin hole lens' (Fig. 1B). Epoxy glue is used to fit the globe to the hemisphere. On the free back surface of the globe two black orthogonal axes are painted to illustrate the four retinal quadrants i.e., superior nasal, superior temporal, inferior nasal, and inferior temporal (Fig. 1C). Location of the emerging point of the optic nerve must be indicated and, additionally, represented as a black cardboard circle adhered on the retinal screen at the corresponding anatomic location (Fig. 1C). This piece of cardboard avoids any image projection on the retinal screen emulating the physiological scotoma, i.e., emergence of the optic nerve.

The eye analog is glued to the base of the model with a wood support high enough to maintain the optical axis collimation with the visual field center so that the image of evcry bulb in the visual field is projected on the corresponding retinal quadrant. On the other hand, the visual field is represented by a 35 × 35 × 0.3-cm wood screen painted white on which two black orthogonal axes (4-mm-thick line) are painted to illustrate the four visual field quadrants i.e., two superior, two interior, two nasal, and two temporal (Fig. 1D). A bulb socket is glued in the middle of every field quadrant, and the bulbs (115-V, 15 W) are installed (Fig. 1A and D), representing the light point from each visual quadrant. Wiring of bulbs is made on the back of the visual field screen to four monopolar 115 V switches, one for each bulb in the visual field. This allows any visual field quadrant to be switched on individually or in any possible combination. For better discrimination, three bulbs were painted with diluted color (blue, red, and violet) and the fourth was left uncolored. The switches are fixed on a 60 × 20 × 2-cm heavy wood base that also supports both the eye model and the visual field screen. The visual field screen is glued to the wood base, but the eye model is freely movable forward or backward by means of a metal guide fixed to the heavy wood base.

To illustrate the perimetric examination, another bulb socket is fixed perpendicular to a rigid plastic tube 45-cm long and 1 cm in diameter. The wiring is made through the tube and connected to the line with a switch. A pencil holder is glued to the end of the tube exactly on the back side of the bulb socket (Fig. 1E). Another 35 × 35 × 0.3-cm wood screen painted white without any bulbs but with the visual field division is located just in front of the first screen with a sheet of white paper attached to its surface. This paper will be used for perimetric mapping.

**PROCEDURAL NOTES**

The presentation of the model is initiated by indicating some anatomic features of the eye, i.e., sclera (white styrofoam hemisphere), retinal quadrants description (opaque glass globe), coroides (between sclera and retina), emergence point of the visual nerve, fovea, and the ora serrata line (all marked on the glass globe). Thereafter, the visual field quadrants are described. Switching on one visual field quadrant and viewing its retinal quadrant projection begins the functional demonstration of the image inversion. Activation of visual field quadrants is done in pairs using the following sequence: 1) superior, 2) inferior, 3) nasal, and 4) temporal. This improves students' comprehension of the bidimensional image inversion. At this point, colored bulbs and their projected images are especially useful. The incidence angle of the four bulbs to the eye can be modified by moving the eye model forward or backward. To illustrate the concept of peripheral vision and its retinal projection, the eye model is progressively moved toward the visual field screen, widening the light incidence angle. The retinal projected images will progressively separate from each other approaching the ora serrata line. It should be pointed out that the ora serrata line of the model is much more posterior than in the human eye, which reduces the model visual field, but this fact will not affect the main objective to understand the bidimensional inversion of images on the retina.

For perimetric demonstration, all visual fields are switched off. The second wood screen without bulbs is located just in front of the bulb-carrying screen, and the displaceable bulb/pencil stick is switched on. A
circle of black paper can be adhered to any place on the retina to serve as a lesion producing a scotoma. Two students are used for the demonstration, one as the examiner and the other as the subject. Searching, slow movements of the bulb performed by the examiner on the visual field are reported as viewed or not by the subject seated at the back of the eye model (retinal side, see Fig. 1B) and marked on the perimetric report sheet by the examiner by pressing the pencil attached to the back of the moving bulb on a white paper adhered to the wood screen. In this way the shape and area of the lesion and scotoma simulated by a black cardboard circle adhered to the retina analog can be easily determined.

This simple and low-cost model has repeatedly proved its capability to illustrate not only basic but also more advanced concepts of eye physiology to medical, dentistry, and nursing students. These concepts involve the retinal projection of the visual field, bidimensional image inversion, blind point determination, visual field and retinal quadrants, perimetric principles, and determination of scotoma.

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