Common entoptic phenomena and their clinical significance

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Dr Janet Voke BSc PhD

MANY PATIENTS PRESENTING to optometric practice are concerned about 'spots' or transient formations in their visual field, which move with eye movements and then disappear as quickly as they came. They can be particularly troublesome to elderly people, especially where the pupils are small, because the entoptic image, which may be moving, is superimposed on the real image. For the most part these phenomena are harmless and inconsequential, but because they often relate to retinal function and its blood supply they have value in diagnosis.

Entoptic phenomena usually originate from within the eye, as a cause either directly or indirectly, although the literal Greek translation is "things perceived within vision". They must not be confused with hallucinations though, which have no obvious structural foundation and are generally psychological distortions from cortical misinterpretations of the world.

A great variety of entoptic phenomena are observable and their causes are almost as numerous. Some have optical causes such as diffraction effects or polarisation of light, whilst others have a more physiological origin and include vascular effects and variation in pigmentation in the macula. Electrical nerve discharges account for a whole group of additional 'phosphenes'. The role of higher cortical visual centres in the appearance of entoptic phenomena also cannot be ruled out in some cases, although their contribution is difficult to analyse. Another group of phenomena, halos, are mostly seen in pathological eyes and so have valuable clinical significance.

Floaters

Perhaps the most commonly observed entoptic phenomenon is floaters, otherwise known as 'muscae volitantes' or 'flying gnats'. They appear as irregular colourless spots or ellipses, which look like 'ghost cells', often observed by an individual when staring at a bright background. Some may be shadowy, and therefore appear to be dark, but in general they occur in clusters moving in a curved path, usually downward. Floaters will often be seen to follow eye movements but then tend to 'over-shoot' the fixation point and then gradually fade. They are called 'floaters' because if one tries to inspect them closely by trying to keep up with them, they simply float away and cannot be tracked.

Floaters are typically found in the vitreous, usually as small opacities that are remnants of embryonic material and/or proteins of the vitreous. They are seen because of the shadows they cast on the retina and are seen more easily if they lie close to the retina as they obstruct much more light than those further away.

Floaters of a pathological nature tend to be due to retinal detachment or a small haemorrhage, for example following ocular surgery or a head injury. In the former case, floaters tend to be of recent onset, quite substantial in number and are often accompanied with symptoms such as flashing lights and/or a shadow or veil across the patient's vision. This type of symptomology will require emergency investigation at a hospital A&E department. In the latter case, haemorrhages occur when small retinal vessels leak and blood is released into the vitreous. Very careful examination in this situation will show a distinct bright central ring surrounded by multiple outer rings of light and dark. They are believed to be due to the diffraction effects of erythrocytes freely floating in the liquid of the foveal pit, about 300µm from the retinal cone receptors, or in suspension in the vitreous. These types of floaters move at a rate of about 0.5mm per second and are seen best against a blue sky because of the absorption properties of haemoglobin. They are not seen at the fixation point because the fovea is avascular. Normally the effect is monocular and this has obvious clinical advantages for diagnosis and differentiation of a retinal condition.

Floaters can be seen in detail by means of a simple homemade entoptoscope. This type of instrument is produced by placing a pinhole of about 16mm in diameter in front of the eye. It causes concentrated parallel light to be incident on the retina and provides a useful method of making shadows more obvious. However, this group of phenomena is so common that artificial aids are usually not required to see them.

Vascular scotomas

The retinal blood vessels lie in front of the photoreceptors and they can, therefore, cast shadows and produce a permanent or temporary 'streak-like scotoma'. Retinal capillaries are particularly noticeable to patients during ophthalmoscopy because the ordinary adaptation processes of the photoreceptors are upset by the sudden change in illumination over a selected retinal region. A slit lamp beam moved across the sclera is also often sufficient to bring into view an afterimage of the vascular tree. The name angioscotomatra is given to these areas.

Viewing through a pinhole is again a helpful means of detecting these entoptic streaks; slight movement of the pinhole to change the illumination and the adaptation state will bring the vasculature into view. The blind spot is an extreme example of a retinal scotoma and could be classed in this group. However, this missing area of vision is compensated for in binocular vision by the contralateral eye. In some pathological conditions such as papilloedema, however, the blind spot becomes enlarged and interferes with normal vision.

The scintillating star-shaped scotomas typical of migraine are thought to be of cortical origin, although they often change their location in the visual field. Migraine sufferers report a great many entoptic experiences and these can be very variable and often transitory because of the vascular changes associated with migraine, and related pulsation of blood vessels. This is in contrast to pathological causes, such as in retinal detachment, which tends to be located in a constant aspect of the visual field (see later).

On some occasions patients may report that upon waking they observe tiny spots in their central vision that are usually dark, elliptical or circular in shape, and can disappear and reappear. It is most likely that these symptoms are related to blood circulation to the eye, which changes suddenly from when the body is supine to then being up straight. This type of entoptic phenomenon may also be classified as phosphenes (see later).

Physiological haloes or coronas

The anatomical arrangements of a number of small structures in the eye can cause them to act as diffraction gratings, dispersing light to create patterns on the retina. These are referred to as physiological haloes or coronas, and have varying causes. The cells of the corneal epithelium, pigment on the corneal endothelium, and the radial fibres of the crystalline lens produce diffraction effects, while mucous or other foreign bodies in the tear film can also have a similar effect. The radial fibres of the lens, for example, will produce a diffractive ring of about 3in in size. The diameter of the halo varies inversely with the diameter of the diffractive particle, or spacing of the lens fibres, and is smaller if these are nearer to the retina.

Descartes described a physiological corneal halo in 1637. A bright white central ring was observed to be surrounded by three coloured circles, the inner being red, the next being green and the outer being red. Depending on the radii of the rings, it is likely that such haloes have their origin from tiny particles in the tear film. Such halos are sometimes seen on waking, when there is mucous in the tear film, and if present may be difficult to suppress because blinking unusually fails to remove them.

Individuals do not often report physiological haloes. Indeed, they may only be seen during an eye examination. For example, patients quite often report seeing ring haloes around bright spotlights in a darkened consulting room, usually of between 4^0 and 6^0 in in angular subtense, due to diffraction by the crystalline lens fibres and the pupil margin.

Pathological haloes

Pathological haloes have several causes, some of which can be sinister and require immediate attention. The increased mucous secretion associated with chronic conjunctivitis is a frequent cause of troublesome haloes. Conjunctival damage in snow blindness also may produce pathological haloes.

Perhaps the best known occurrence of pathological haloes are those associated with angle closure glaucoma, with this symptom being key to the diagnosis of this condition. The raised intraocular pressure (IOP), which results from a failure of the aqueous outflow mechanism at the trabecular meshwork, leads to a higher fluid content in the tissues of the anterior media (oedema), causing the scattering of light. The glaucomatous halo is very bright, around 9^0 in subtense but variable in size because of the variety of droplets causing it. It may appear with a blue-green coloured inner ring and a yellow-red coloured outer ring.

Generally, halos due to angle closure glaucoma can be seen when patients are examined with the slit lamp biomicroscope, whilst they can also be

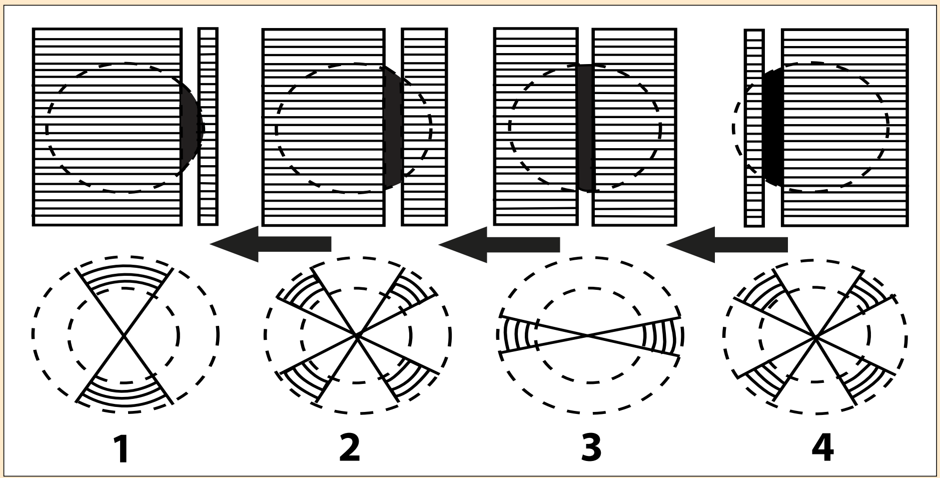

Figure 1
A simple method to distinguish between pathological and physiological haloes using a stenopaeic slit. Placing the vertical slit in front of the pupil off-centre will deny most radial fibres of the lens with light. In position (1) diffraction is partial and only horizontal fibres are seen. As the slit moves across the pupil to position (2) radial fibres are seen in four positions and a more complete diffraction pattern is experienced. When the slit is in the centre of the pupil (3) vertical fibres are seen in two positions along a horizontal axis. In position (4) the pattern is similar to that of position (2).

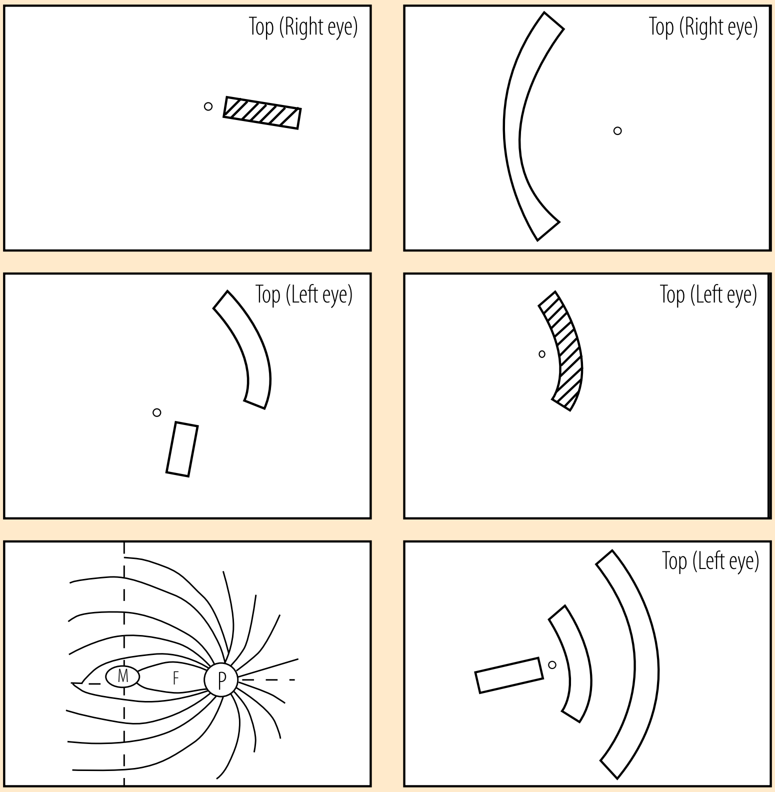

Figure 2
Arrangement of the retinal nerve fibres relative to the optic disc is shown in the bottom left panel whilst the remaining panels reveal appropriate stimuli for demonstrating the blue arcs effect (see text for details).

particularly troublesome after surgery. However, if the rise in IOP is gradual, for example with only a partially closed angle, then corneal oedema may not occur if the endothelial layer is able to accommodate this change. In eyes with poor endothelial function, haloes are more likely to be experienced.

Contact lens wearers may also observe haloes as a typical sign of overwear syndrome, whereby corneal oedema occurs from hypoxia, or due to contact lens trauma. Such patients should be advised to cease contact lens wear until their symptoms disappear, whilst re-fitting to modern silicone hyrdogel materials would be ideal.

Pathological haloes can be differentiated from physiological haloes primarily by their size, with the former being larger than the latter. Pathological haloes also tend to be much brighter than physiological haloes, and less fleeting. A simple means of distinguishing between the physiological and pathological halo is to pass a straight edge or stenopaic slit very close to the eye across the pupil (Figure 1). The pathological halo will be seen to be dimmer whilst in the case of a physiological halo the horizontal part gradually disappears. A wheel-like movement of haloes is also seen only in those with a physiological halo.

Phosphenes

Vague visual sensations that are brief and intense, white, yellow or blue in colour and move in the visual field are a common experience, particularly noticed in the dark-adapted state. These are known as phosphenes and they represent retinal stimulation by a source other than light. It is possible that phosphenes are caused by electrical charge in the neural network of the retina and the breakdown and regeneration of visual pigment, although the retina is not directly stimulated by light at this time. Cortical areas of neuronal activity are also likely to be involved. Indeed it has been shown that these sensations can be produced by direct electrical stimulation of the visual cortical neurones, during brain surgery, even in those patients that have no sight. However, it has also been shown that these sensations fluctuate depending on accommodative state, eye movements and respiratory rate, which indicate an ocular source.

Perhaps the most commonly encountered phosphenes in optometric practice are patient symptoms of flashing lights, which are reported in cases of suspect retinal detachment and/or posterior vitreous detachment (PVD). This represents a mechanical stimulation of the retina by traction from the vitreous and such patients need careful examination, particularly of the peripheral retina with indirect ophthalmoscopy techniques, to identify any pathology requiring urgent attention.

Phosphenes can also be invoked by pressing the globe with the finger. Indeed, this is perhaps a useful tool for assessing any residual retinal function, for example in those patients with dense cataract that obscures the fundus view. Where there are atrophied retinal areas, e.g. co-morbid age-related macular degeneration (AMD), this will not produce any visual sensations and therefore this can indicate the potential benefit, or lack of, for cataract extraction. It has also been reported that rapid version movements of the eyes can induce these types of sensations, through traction from the lateral and medial rectus muscles.

Blue Arcs

Purkinje first noticed entoptic sensations of blue arcs in 1825. These arcs were seen one above and one below the fixation point, when viewing an open fire, and corresponded to the projected path of retinal nerve fibres from the point of stimulation to the optic nerve. Purkinje also noticed that as he fixated further from or closer to the fire, the arcs appeared to move apart or closer together whilst nasal viewing gave the best sensation of the arcs.

Originally believed to be a phenomenon of light scatter, some further rather implausible theories were suggested, including bioluminescence or emission of visible light or ultra-violet (UV) radiation from the retinal nerve fibres. It was only when the arrangement of the optic nerve and retinal nerve fibres was described by Wallace in 1836 that Muller was in 1855 able to fit this anatomical relationship together with the blue arc sensations. The theory is accepted today and the arcs are believed to result from possible electrical discharge of ganglion cells in the retina in the papillo-macular region around the retinal raphé (Figure 2). The loci of the arcs are, of course, very similar to the nerve fibre pattern of the papillo-macular bundle. This arrangement is often seen with an ophthalmoscope using red-free light. The effect can be produced binocularly as well as monocularly, and in the former case the arcs of the two eyes appear to join to form a figure that looks like the number 8 rotated to its side (i.e. ∞).

Because the demonstration requires careful fixation and lasts only for a second at a time, the arcs are not often seen casually. But only a very simple arrangement of a red filter over a 60-watt bulb and some black card is needed to give the optimum conditions. Minimal dark adaptation of between two or three minutes is ideal and since the arcs appear to come and go it is helpful to enhance the effect by spending similar periods in the light, every few minutes, while viewing the phenomenon. Prolonged dark adaptation ruins the effect. A small fixation spot is made in the card with the areas indicated in Figure 2 cut out in addition.[1]

Troxler Effect

A rather different afterimage perception clearly related to particular retinal regions can also be seen with the Troxler effect. After fixating on a fairly coarse sinusoidal grating (one cycle per degree) of average luminance, the afterimage seen on a blank field of similar luminance immediately following is not uniform. It is as if the peripheral afterimage is considerably retarded with respect to the central fovea after-image. It is likely that the two retinal pathways, the sustained (magnocellular) system controlling central cone vision, and the transient (parvocellular) system controlling peripheral vision, are involved in this entoptic experience, but a mid-brain (lateral geniculate nucleus) or cortical site of origin is another possible explanation. This is especially so since the effect is related to retinal adaptation, which occurs more rapidly in the peripheral retina due to larger receptive field sizes. In the central retina, receptive fields do not adapt quickly since small saccadic eye movements associated with steady fixation produce an 'on-off' effect.

Conclusion

Entoptic phenomena are a wide range of temporary visual sensations that provide a fascinating insight into the functioning and optical features of many parts of the visual system. It is clear that when patients complain of significantly disturbing spots, shadows and arcs of light in their visual field, the diagnosis may point to something more than mere harmless floaters. A later article in this series, on macular pigment, will describe two further entoptic phenomenon, Maxwell's Spot and Haidinger's brushes, both of which are related to the yellow pigment that is found here.

About the Author

Dr Janet Voke is a prolific writer on visual subjects for a wide variety of professionals and has lectured to optometrists and dispensing opticians in the UK and Europe for over 30 years.

References

1. Moreland J D (1969). *Retinal topography and the blue-arcs phenomenon.* Vision Res. 9:965-976

Module questions Course code- C-11411

1. Which one of the following is TRUE? Entoptic phenomena are usually:
a. Harmless
b. Indicative of disease
c. Coloured
d. Troublesome to the patient

2. Entoptic visualisations of media opacities can depend on:
a. Refractive and optical density aspects of opacities within the eye
b. Retinal blood supply
c. Tear film and mucous distribution of the cornea
d. All of the above

3. Which one of the following is thought to be a cause of floaters?
a. Free floating red blood cells in the vitreous
b. Free floating iris pigment cells in the anterior chamber
c. Hair-like fibres in the vitreous
d. Variations in density of the aqueous humour

4. Pathological haloes are often reported in patients with which one of the following?
a. An increased blink rate
b. Silicone hydrogel contact lens wearers
c. Corneal vascularisation
d. Glaucoma and conjunctivitis

5. Blue arc phenomena are observed for which one of the following reasons?
a. Blue wavelength absorption by the lens
b. Rod receptors are more sensitive to blue light than cones
c. Electrical activity in certain retinal neurones
d. Electrical discharges set up between the front and back of the eye

6. Which of the following advice should be given to patients who experience excessive troublesome entoptic phenomena?
a. To wear spectacles with dark lenses
b. To try to ignore them
c. To see their GP
d. To instil artificial tear drops once a day

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Module questions

Course code- C-12756

1. The contact lens material known as balafilcon A III 4M has what properties?
a. It is an ionic hydrogel lens with water content greater than 50%
b. It is a non-ionic rigid lens with low water content with surface modification
c. It is an ionic hydrogel lens with water content less than 50%
d. It is a non-ionic, hydrogel lens with water content less than 50%

2. Which of the following approaches does NOT enhance wettability when lenses are worn?
a. Incorporation of phosphorylcholine into lens material
b. Lipid deposition
c. Plasma treatment of the surface
d. Increasing the stability of the tear film

3. Which of the following is likely to improve comfort and wettability of a hydrogel contact lens on insertion?
a. Hydroxypropylmethyl cellulose (HPMC) added to the packaging saline
b. Hyaluronic Acid (HA) added to the packaging saline
c. Polyvinylpyrrolidone (PVP) added to the packaging saline
d. All of the above

4. Which of the following is NOT likely to improve long-term wettability of a contact lens surface?
a. Utilising a 'no rub' approach to lens care
b. Continuous wear of a standard hydrogel contact lens
c. The addition of high molecular weight polymer to the lens matrix
d. Plasma treatment of a gas permeable lens

5. Which measure of modulus is closest to simulating the deformation force on a contact lens from blinking?
a. Elastic modulus
b. Tensile modulus
c. Stiffness
d. Initial modulus

6. Which of the following is a typical mechanical complication of hydrogel contact lens wear?
a. Superior epithelial arcuate lesion
b. 3 & 9 staining
c. Chalazion
d. Pingueculae

7. The science of tribology is the study of?
a. Biocompatibility between two membranes
b. Friction in bioscence
c. Organisms that colonise biocompatible surfaces
d. How bacteria group together on a contact lens surface

8. How is wettability achieved with the Daily AquaComfort Plus (CIBA Vision) lens during wear?
a. Extra PVA that is released from the lens during wear
b. HPMC added to packaging
c. PEG added to packaging solution to combine with the PVA
d. All of the above

9. Which of these tear film constituents carries a positive charge?
a. Albumin
b. Chloride
c. Lysozyme
d. Hydroxide

10. Which of the following statements about silicon hydrogel lenses is CORRECT?
a. They tend to have less denatured protein than standard hydrogels
b. They tend to attract less lipid but more 'active' protein
c. They tend to attract lipid only
d. They tend to attract less protein but more lipid

11. Which pattern of staining is characteristic of a solution compatibility problem between silicone hydrogels and multipurpose care solution?
a. Central punctate staining appearing immediately after lens insertion
b. Peripheral punctate staining appearing immediately after lens insertion
c. Peripheral punctate staining appearing 2-4 hours after lens insertion
d. Central punctate staining appearing 2-4 hours after lens insertion

12. Which of the following would reduce hydrogel lens transmissibility?
a. Reducing centre thickness
b. Increasing water content
c. Incorporating a wetting agent in the polymer
d. Lens dehydration

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