ASSESSMENT OF VISUAL FUNCTION

The process of visual perception requires (i) accurate focussing of light by the optical system of the eye, (ii) photo-chemical processes in the retina which lead to nervous impulses, and (iii) central interpretation of this information which is correlated with past experience by the brain. In this experiment attention will be confined to investigation of the optical system.

THE OPTICAL SYSTEM OF THE EYE

In the normal relaxed eye parallel rays of light (i.e. from object at infinity) are brought exactly to focus on the retina. The far point is therefore an infinity. About two-thirds of the refraction occurs at the corneal/air interface, and one-third at the lens (i.e. 42 diopters by the cornea, 23 diopters by the lens - see below).

In order to focus light on near objects, the total refractive power of the eye must be increased, which is done by increasing the aveture of the lens by the muscles of accommodation. The strength of the lens is usually defined in diopters.

$$\text{Strength in diopters} = \frac{100}{/\text{Focal length in cm}}$$

convex (converging) lenses are assigned the prefix positive, and concave negative. Thus a diopter diverging lens is called -2D.

In a young person during accommodation the lens should be able to increase its power by about 10 diopters; substitution in the formula above will therefore give a near point of about 10 cm. From childhood onwards the lens becomes progressively less malleable and hence the power of accommodation also decreases. In childhood the power of accommodation is about 14 diopters, and the near point is 7 cm; at 20 years the near point is about 10 cm, and by about 45 it has receded to 25 cm, which means a power of accommodation of only 4D. By 60 only about 1 dioptres of accommodation remains.

Defects of the Refractory System

1. Myopia (short sight). This common refractive error is due to a relatively too strong tidal system for the length of the eye. Rays of light are brought into focus in front of the retina and a blurred image results even when the lens is relaxed completely. Thus, although near objects are seen clearly, beyond a certain distance everything is blurred. Unfortunately, even a minor degree of myopia has relatively severe consequences: for example a myopia of ID means that the unaccommodated eye will focus objects at 1 metre distant (nearer by accommodation) but objects beyond this will be increasingly blurred as the

whole range of distances from infinity to 1 metre represents only 1 dioptre. (Apply appropriate figures to lens formula above).

2. Hypermetropia (long sight). Here the eye is too short for the optical system and even with the eye fully accommodated the rays from near objects are brought into focus behind the near point, therefore, is further away than normal. Some accommodation is required even for distant objects.

3. **Presbyopia** ('eyesight of old age'). This is the state that is reached when the near point has receded beyond the normal reading or working range at about 30 cm, due to lack of accommodative power (see above).

4. **Astigmatism**. This is due to abnormalities of the curvature of the cornea or to a small extent the lens; for instance, the focal length in the vertical and horizontal planes may be different (i.e. there is a cylindrial component to the system). Because of this inequality vertical and horizontal objects require different degrees of accommodation to bring them into focus, and the patient usually complain of blurring of vision at all distances.

5. **Correction of defects**. The only effective method is to place a lens in front of the eye which will cancel out its defects. Myopia, therefore, requires a concave lens, hypermetropia and presbyopia a convex one. Lenses which fit over the cornea itself, contact lenses, are being increasingly used for the correction of visual defects. The space between the lens and the cornea is filled with saline so that any defects of corneal curvature are abolished. Corneal astigmatism is treated by the use of cylindrical component in ordinary spectacles or automatically by the use of contact lenses.

COLOUR VISION

(Note that the following account is a simplified version of the usually accepted theories and is only intended as a basis for understanding the experiment).

The visible spectrum shows a number of characteristic colours each of which covers a range of wavelengths (e.g. red, orange, yellow, etc). If two coloured lights are mixed, the resulting sensation is identical to that produced by a single colour of intermediate wavelength. This can be shown using a suitable instrument which one half of a screen can be illuminated by light of a wavelength chosen by the experimentor and the other half is controlled by the subject who has to match the two halves as accurately as possible. It is found that, in normal people, any colour (including white) can be matched by a suitable mixture of three primary spectral wavelengths. The three primaries are chosen so that any one cannot be produced by other two; thus red, green and blue are primaries (these are not pigments remember). The total intensity of illumination is kept constant, but the subject can vary the relative contribution of each light independently, thus the contribution of a single colour may be varied from zero to its being the sole source of illumination.

Mechanism of Colour Vision

The most generally accepted theory is the Young-Helmholtz theory which assumes the existence in the retina of three separate colour detecting mechanisms; all colour sensations being resolved from an unequal stimulation of these three, and white from universal stimulation. The sensation of black is due to the absence of stimulation, but a normal retina is required as, for example, at the blind spot nothing IS SEEN BUT blackness.

It appears probable that there are three types of retinal cone each of which contains one of three pigments (red, green or blue) and although there are objections to the Tri-chromatic theory of Young-Helholtz, it serves to explain most of the phenomena encountered in the eye. Shown below are theoretical wavelength curves for three hypothetical receptors maximally sensitive to red, green and blue.

Fig. 1

A 'blue' cone would respond maximally to the short wavelengths and only a little to lights in the middle range; a 'green' one would respond preferentially to the middle regions and so on. From the diagram it is clear that a yellow light of 6,000 A would excite the red mechanism more than the green and the blue not at all whereas a light of 5,000 A would excite the green most of all and the blue and red more or less equally. Thus an identical colour sensation is produced by, say, a yellow light of 6,000 A as by a suitable mixture of red and green. For lights in the lower wavelengths (e.g. 5,000A) some blue light has also to be added to the red and green before a match is obtained.

Colour deficiency or colour blindness

Congenital colour blindness occurs in 4-8% of males and 0.4% females. It is transmitted through a sex-linked gene in the X-chromosome and is therefore recessive in the female. The most common type is a difficulty in differentiating between red and green. Such people accept colour matches (see above) made by normal subjects with three reference lights but can make their own matches with only two (see also below) one of the matching lights being superfluous. These people are termed di--chromats and the assumption naturally follows that this type of defect is due to the inactivity of one of the three receptor systems. When only one light is required, i.e. the subject is completely colour blind, the rare condition of monochromatism is said to be present. Other colour defective subjects may require all three lights for their colour matches, but their matching differs from the normal (commonly in the use of red) to such as extent that neither the normal nor the defective can accept each other matches; these people are known as anomalous tri-chromats and the conditon is one of the commonest forms of colour deficiency. The main classification of colour blindness is thus based on the number of reference lights required for matching and whether or not they are used in a normal manner.

Further classification of di-chromatism

The terms for the different deficiencies derive from the Greek for 1st (proton) 2nd(deuter), and 3rd (tritan). The suffix-anopia complete lack of a particular colour range (e.g. protanopia), and the suffix anomaly indicates that it is reduced (e.g. protanomaly). Classifically protanopes (red blind) are assumed to have lost the red sensation. Thus the visible spectrum is shortened for a protanope and reference to the diagram above shows that above about 6,500 A no colour sensation is experienced, between 6,500 and 5,000 A the sensation is of green only (although it may be called yellow). With the introduction of blue at about 5,000 A changes in colour will be appreciated and blue at discriminations is approximately normal. The normal tri-chromatic person will see a mixture of red; green and blue light which stimulates his cones equally as white. As the protanope is missing red sensation, the red part is lost on him and although he will accept the normal tri-chromatic person's white as white, he will match it with a mixture of blue and green.

Deuteranopes lack the green sensitive pigment and the anomaly is fairly common. Tritanopia is due to the lack of blue pigment and is very rare. The visual loss experienced by dueteranopes and tritanopes can be worked out with reference to the diagram in a similar manner to protanopia above.

1. **Spectroscopic tests**. include devices that will allow observation of an isolated spectral colour with the whole spectrum. Although these are the most scientifically accurate methods they are not generally applicable.

2. Pseudoisochromatic diagrams (e.g. stilling and Ishihara's charts) are a series of plates containing panels filled with coloured spots, from among the latter a figure can be traced in spots of a different colour apparent to a normal person but specifically misinterpreted by colour blind subjects e.g a normal person will differentiate red from orange whereas the protanope cannot. These give a fairly accurate assessment of the common red/green defects and are most convenient for routine use.

EXPERIMENTS

I) Visual Acuity

The Snellen Test Chart is the one almost universally employed in routine tests of visual acuity. It consists of sets of letters designed so that the details that have to be resolved in order that they may be legible subtend the angle of one minute at different distances (the whole letters subtending five minutes of arc). Thus the details of the largest letter subtend one minute to an eye 36 metres away, the next largest subtend the same angle at 18 metres, and so on, the distances corresponding to each row being marked underneath. It is considered that the normal eye should be able to resolve details separated by one minute of arc - this is the basis of the test.

The subject is seated exactly 6 metres away from the chart and told to read down the chart. Note the number of the last row that he reads correctly. If this is 6, it means that he can resolve points that are separated by one minute of arc, i.e. that he has normal vision. If the number, were, say 12, this would mean that the minimum angle was doubled and the acuity halved: this is expressed conventionally as 6/12 vision. Note that as far as the eye is concerned, 6 metres is the same as infinity, so a long sighted person should be found in this test to have normal acuity.

<u>The astigmatic fan</u> consists of lines radiating out from a centre. If the eye is astigmatic, not all these lines can be focussed sharply at once. Subjective sensation: If you have normal sight you should imitate the subjective effects of short sight, long sight and astigmatism holding up suitable lenses before an eye, while looking at the test charts. You will then be able to understand exactly what it is that patients complain of.

<u>Tests on refracting system.</u> There are only two sets of trial lenses so you must organise yourselves to rotate around the various experiments. Note how the box of test lenses is arranged (c-carylindrical, s = spherical) <u>Put the lenses back in the right places.</u>

a) **<u>On a normal subject.</u>** Seat him 6 metres in front of the test chart and adjust a trial frame until the lenses in it are centred to the eyes. Shade one eye and find the lowest line of the chart that can be read correctly. Insert a + ID lens. This should produce blurring. If it does not, it suggests that the subject was accommodating sightedness. Having found the strongest convex lens that the subject can bear, now insert progressively stronger concave lenses. As each is inserted, the subject accommodates to compensate. Find the strongest concave lens that can be worn without blurring. Reading the test chart is not a good test for blurring. The letters become difficult to read partly because they are diminshed in size by the concave lens. The difference in strength between the strongest convex and the strongest concave gives the range of accommodation.

b) **<u>On subject who wears spectacles.</u>** If possible choose a subject who does not have severe astigmatism. Seat him 6 metres in front of the test chart and measure his visual acuity. Question him about his disability in order to decide whether he is long sighted short sighted. If the former insert progressively stronger + lenses until visual acuity just begin to diminish below its maximum.

This, **<u>the strongest convex lens,</u>** is the required correction. If the subject is short sighted, put in concave lenses until blurring just begins. About ID less than this is the appropriate correction, i.e. the <u>weakest concave lens</u>.

If you have a suitable astigmatic subject as found from the astigmatic fan, try correcting his defect with a combination of cylindrical and spherical lenses.

c) Following assessment of the visual acuity of a normal subject place one of the lenses 'A' or 'B' in the trial frame and determine its strength by using appropriate lenses from the trial box to restore normal vision. Determine the strength of the other unknown lens on another subject.

<u>Note:</u> It is not always possible to use subjective methods for assessment of visual acuity (e.g. in babies) and in these circumstances an objective method is the only method applicable. **<u>Retinoscopy</u>** is the usual method and even in adults this should always be performed. It requires practice before useful results can be obtained so it is not included here, but those interested might find time to look up the method in the textbooks.

ii) **Near point**. Determine the near point using the apparatus provided. Slide the test card towards the eye until it is just in focus, if it is nearer the print becomes blurred.

iii) **Colour Vision**. Use the Ishihara tests of colour discrimination to discover colour blind subjects. Determine the affected region of the spectrum and the degrees of severity. Do your results permit any decision as a double classification of the subject's defect?

Visual Field

It is often clinically important to determine whether or not the peripheral visual field is normal or whether there is restriction of the field or localised loss of vision. The perimeter is a device with a chin rest so that the eye occupies the central point of a perimeter which a semicircular arc, roughly concentration with the retina can be rotated to occupy any chosen meridian. The subject is instructed to fix his gaze on the central point of the arch continuously and to indicate when he can see a white disc which is moved in from the periphery by the observer. This point is noted and an appropriate mark made on the chart.

Experimental

Using the perimeter examine the visual field of one of your eyes (or both if you have time) and enter the results on the chart in the schedule.

iv) **Inspection of the eye: the Ophthalmoscope**

This is an instrument that enables you to shine a beam of light into the subject's eye, and then look along the centre of the beam. The rotating disc contains small lenses that can be interposed between your eye and the subject's eye: their strength in Dioptres is shown through a small window. If both you and he have normal vision, and both focus at infinity, it is easy to see that an image of his retina will be focussed on yours (and vice-versa) so no lens is necessary. The lenses are used only to correct for refractive defect in either of you. A strong + lens may also be used as a magnifying glass for close examination.

Method of use: To look into the subject's right eye, use your own right eye. Have him comfortably seated, and ask him to fix his gaze on some distant object. Rotate the ophthalmoscope disc until no lens is interposed, then look through the hole at the subject's eye. Switch on the light, and bring the ophthalmoscope (and your eye) closer and closer to his pupil. Through his pupil you will see the pinkish glow reflected from the retina, when you are close enough this will be seen to be traversed by small blood vessels, and by moving the ophthalmoscope you will be able to trace them back to the optic nerve head. Should the image be blurred, rotate the disc until it is sharply in focus. The closer you can get to his eye, the better. Practice on different subjects and you will find that it soon becomes quite easy to see a great deal of detail in the eye. Ophthalmoscopy is a vital part of any thorough medical examination as it is only in the retina that arterioles can be seen to undergo the changes characteristic of, for example, high blood pressure, or nephritis. The transparency of the media may be found to be impaired by a cataract, while by noting what lens it is necessary to interpose, some information is obtained about the reflective condition of the eye. In order to facilitate examination of the retina it is often useful to prevent pupillary constriction by the use of Atropine. The demonstrator will instil a drop of an atropine derivative (homatropine) into the eye of one or two volunteers of normal sight, and all the group should take the opportunity of examining his eye with the ophthalmoscope. At the end of the experiment further action of the homatropine will be antagonised by the application of a drop of the anticholinesterase eserine.

Experimental

1. Practice the use of the ophthalmoscope using the practice eye.
2. Examine the pupil dilated by atropine
3. Examine the eye of your partner

Results

Express succinctly results of your experiments, namely:

i) visual acuity in both eyes. Is there any astigmatism? If so in what plane?
ii) what is your near point of vision?
iii) is your colour vision normal? If not, what is the spectral region affected and how severe is the defect?
iv) draw out the peripheral fields of vision on the charts provided in one or, if possible, both eyes
v) have you any relevant comments on the results of the ophthalmoscopic examination of your partner's eye?

It would be profitable if you also considered the following questions at a suitable opportunity.

1. Why is everything blurred under water?
2. What is the far point of a person with 4 dioptres of myopia?
3. as myopics age, are they likely to require stronger or weaker lenses in their spectacles?
4. Why does atropine applied to the eye not only cause everything to appear excessively bright, but blurred as well?
5. What would be the colour defect of a person suffering from a tritanopia?
6. Why are drunks reputed to 'see double'?