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TELESCOPIC SPECTACLES

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At the Annual Meeting of The British Medical Association, 1928, a short paper was read on the subject of "Telescopic Spectacles." A brief history of their development was given, together with some notes on their general construction and use. Apart from particulars useful for the surgeon and dispensing optician when prescribing and fitting, very little attention was given to the question of design. Nothing was said with regard to the many difficult problems confronting the designer. For many years, although the advantages of magnifying spectacles had been fully realised and Galilean telescopes had often been tried, very little success had been achieved, largely owing to the poor quality of the image due to excessive aberrations. Some small success had certainly been obtained with spectacles for high myopia, but those for emmetropia and hypermetropia had been so inferior that surgeons had ceased to consider the possibility of their use, and the spectacles were only recommended for cases of excessive myopia with macular impairment. A further cause of failure was doubtless due to bad fitting and the use of insufficiently rigid frames.

In recent years telescopic spectacles have begun to gain favour and reputation, largely owing to the renewed efforts of opticians to produce a spectacle of real practical value. And in this country

much of the experimental work was done by Messrs. Theodore Hamblin, Ltd. Recent developments in the making of optical glasses have assisted these efforts very considerably. In this paper it is hoped to give some idea of the numerous problems which have had to be faced.

It is necessary, first of all, to realise what purpose may be served by the spectacles and the consequent requirements to be met. If well made they should be beneficial to several classes of patients:—those with defects of the retina due to excessive myopia; others who, though approximately emmetropic, have poor vision, due for instance, to partial opacity of the cornea or crystalline lens as in incipient cataract, or to a feebleness of the retina in responding to stimulation by light. All such patients should benefit by the magnified image since it covers a greater area of the retina thus stimulating more rods and cones. Further, these spectacles should be of service to patients with local areas of partial or complete choroidal atrophy. The image of an external object formed by the unaided eye might fall entirely within an insensitive area of the retina and therefore would not be seen at all. The image of that same external object seen through magnifying spectacles would cover a larger area of retina; this image might extend over an area greater than the atrophied region, and the existence of the object will in this case at least be realised, even if not clearly depicted over its whole extent.

In recent years surgeons themselves have made very successful use of these spectacles for operating or close inspection work. They give an enlarged stereoscopic image at any working distance required and leave the hands quite free. Further they can be combined with ordinary distance or bifocal spectacles, so that the wearer may be able to use the magnifying spectacles at will without making any change in his equipment. To do this is frequently a great advantage. If binocular loupes are used, the field is restricted and it is impossible to see into the distance without removing them. Using a monocular loupe, a surgeon is free to use one eye for normal vision and the other for close work, but he loses the advantages of stereoscopic vision. When telescopic units are fitted into his ordinary spectacles he has only to turn his head a little to change from vision through magnifying telescopic spectacles to normal vision. Any ametropia of the surgeon, of course, is corrected in the telescopic spectacles. This use for telescopic spectacles was quite impossible in the days when only the myopic form could be made to give an image that was good enough to confer any benefit which should be derived from the magnification.

This brief consideration of the possible uses of telescopic spectacles renders the requirements fairly evident. There are

numerous factors, both human and optical, which have to be borne in mind: the spectacles may have to be worn constantly. It is therefore most important that they should be comfortable and convenient to wear; they must not, for instance, attain the bulk or weight of even the most delicate opera glasses. Also it is desirable that they should present a pleasing appearance. They must give an erect image of course; inverted images would be quite useless. Further, they must give a large, tolerably flat and well-defined field, so that the wearer does not feel seriously restricted in his outlook. A small field would be uncomfortable, fatiguing and inconvenient, since it would necessitate constant movement of the head to cover anything like a useful field. In spectacles for distant vision a small field might be distinctly dangerous; the field must be sufficiently large to enable the wearer to move about in safety. He should be able to see that he is approaching steps, street crossings and other obstacles before he is right upon them. For reading it is desirable that the wearer should be able to see, at an average reading distance, a whole line of print of an average sized book, and also the neighbouring lines above and below.

The spectacles should give a useful amount of magnification, enough to assist the wearer and not so much that he will be worried by it. Magnification causes the image to move at a greater rate than the head or the object; if this magnified movement of the image is too great it becomes difficult to hold the head steady enough for comfortable observation, or to follow objects already moving at a considerable speed. Moreover, magnification varies inversely as the extent of the useable field of an instrument; for this reason too, the magnification must be kept as low as possible, since field is of great importance. It is fairly generally agreed from experience that $\times 1.3$ to $\times 1.8$ is the most desirable magnification to give. It is sufficient to give the patient the assistance he requires while it is low enough to afford a useful size of field having tolerable definition with a simple optical system. With this low magnification it is also possible to hold the head sufficiently steady.

Magnification will not as a general rule increase the brightness of the image on the retina. In Fig. 1a is given a diagram showing

FIG. 1a.

FIG. 1b.

the maximum diameter of a pencil of light, proceeding from a distant small source, which could enter a pupil of the size indicated. In Fig. 1*b* is given in broken lines the same maximum parallel pencil of light falling upon the eye. An emmetropic telescopic spectacle magnifying $\times 2$ is drawn in front of the eye. Tracing the maximum parallel pencil of light from the eye backwards through the eye-lens and objective (see full lines) it will be seen that the pencil of light leaving the objective is twice the diameter of that entering the eye. In effect, therefore, the eye is receiving a pencil of light twice the diameter of its own pupil; *i.e.*, four times the area. Four times the quantity of light from a star would be imaged in a point on the retina. It should be realised, however, that this does *not* apply to extended objects which are diffusely illuminated, owing to the linear magnification. Certainly more light is received by the spectacles than by the unaided eye, but this larger quantity of light is spread over a correspondingly larger area on the retina. In fact, the brightness of the image per unit area on the retina is actually slightly less with telescopic spectacles than with the unaided eye, because of light losses through absorption in the glasses and partial reflections at the glass-air surfaces.

The spectacles should also have a large exit pupil to ensure that patients, whose vision may be feeble, are always able to use the full aperture afforded by the diameter of their own pupils. Moreover, in order that the spectacles may give all the light possible it is also necessary that the number of lenses should be reduced to a minimum, likewise their thicknesses and the number of glass surfaces exposed to air. Every glass-air surface diminishes the light entering by some 4 per cent. Further, these spectacles must be mounted quite accurately and rigidly before the eyes; this important question of mounting and fitting was dealt with at some length in the previous paper on the subject,* and consequently will not receive further consideration in the present discussion.

The form of telescope selected is invariably Galilean, that is to say, a positive objective and a negative eye-lens separated by the difference of their focal lengths. There are several important reasons underlying this choice. Firstly, a Galilean telescope gives with only two simple lenses an erect image without the introduction of an auxiliary erecting system as is required with an all positive telescope. This is an important matter when both compactness and lightness of weight are essential. The Galilean telescope is not only compact because it needs no erecting system, but also because objective and eye-lens are separated by the difference of their focal lengths and not the arithmetic sum as in

* *British Medical Journal*, September 8, 1928.

the all positive forms of telescope. The Galilean form has a large exit pupil enabling the wearer to use the full diameter of his pupil even in twilight, when it may reach 7 mm. Telescopic spectacles have to work with an abnormally large field, comparable to that of a photographic lens rather than a telescope. For this reason again the combination of the positive with negative lens in the Galilean telescope is advantageous in securing a moderately flat field tolerably free from astigmatism. Further reference will be made to this matter of a flat anastigmatic field. For all these reasons mentioned it will be clear that the Galilean form of telescope is the most favourable.

It will be evident already that the optical designer has very little freedom of choice. The spectacles are required to have a flat, extensive, tolerably well corrected field, yet at the same time they have to be compact and light in weight. The magnification is roughly fixed. The maximum over-all length allowed is so short that the designer is practically forced to take that minimum. The magnification and the separation of the components fix their focal lengths, since :

$$\text{Focal length of objective} = \frac{F_1}{F_2} = \text{Magnification} = M.$$

and $F_1 - F_2 = \text{separation} = d.$

Let us suppose that the magnification is to be $\times 1.8$ and that the separation of the components is to be 10 mm., then

$$F_1 = 1.8 F_2.$$

$$F_1 - F_2 = 10 \text{ mm.}$$

$$\therefore 1.8 F_2 - F_2 = 0.8 F_2 = 10 \text{ mm.}$$

$$\therefore F_2 = +12.5 \text{ mm.}$$

$$\therefore F_1 = +1.8 F_2 = +22.5 \text{ mm.}$$

The designer is therefore free to choose neither focal lengths nor separation, nor a convenient scale. His only freedom is in the shape and nature of the glass composing the two lenses of given focal lengths F_1 and F_2 . Certainly he has a limited choice of separation, but this is so restricted that it can hardly be called a degree of freedom.

Now let us consider what has to be achieved in order to secure the results required while keeping within these severely restricted limits. The spectacles have to work with a large field. The designer will therefore have to contend with all the aberrations of an optical system which are known as the Seidel aberrations and are five in number, namely spherical aberration, coma, astigmatism, Petzval curvature of field and distortion. In addition to these, the spectacles are to be used in ordinary daylight

composed of all the colours of the visible spectrum. They ought, therefore, to be as free from chromatic aberrations as possible. The five aberrations referred to are only the primary or first order aberrations. There are of course higher aberrations, secondaries, tertiaries, etc., but it is quite impossible, also unnecessary, to take these into consideration in a system of few components.

Aberrations of lenses can be varied in several ways. They each obey differing laws and for this reason the decrease of one aberration in a lens system does not necessarily lead to a decrease in others. In fact the reverse is frequently the case; the reduction of one leads to the aggravation of another. For this reason the correction of lens systems is often a difficult matter and except in the most complicated systems a compromise invariably has to be

FIG. 2a.

Chromatic Aberration.

FIG. 2b.

Chromatic difference of Magnification.

made. The exact nature of the compromise is left to the discretion of the designer, and depends on the function of the system and the liberties afforded.

A very brief survey of the nature and effects of the various aberrations, and the method of eliminating them will be of interest in considering the problems connected with telescopic spectacles.

Chromatic aberration is due to the varying refractive power of glass for different colours of the spectrum. The axial image of a white star formed by a simple lens is afflicted with chromatic aberration, and is composed of a number of superimposed coloured images, each slightly displaced from the others along the axis. In Fig. 2a, "B" represents the focus of a ray of blue light, "R" the focus of a ray of red light from the same source, and the length BR is a measure of the chromatic aberration. The amount of the displacement BR grows with the square of the aperture of the lens. There is also another form of chromatic aberration, often known as chromatic difference of magnification (see Fig. 2b) causing the red light from a white extra-axial object to form a larger image than the blue light. This again is due to the fact that glass is less refractive for red light than for blue light. This chromatic error is very noticeable in instruments with a large field, such as telescopic spectacles, particularly along the edges of dark objects seen against a light background. The aberration can only be corrected by choosing

suitable dispersions for the glasses forming the various lenses. Further reference will be made to this matter.

Spherical aberration was mentioned as the first of the five Seidel aberrations. It causes rays of one colour from different zones of an aperture to focus at different points along the axis (see Fig. 3.) The distance "ab" is called the longitudinal spherical aberration and grows directly as the square of the aperture of the lens. That is to say, the aberration "ab" at an aperture of 4 mm. would be four times that at 2 mm. It causes images in every part of the field to look "fuzzy"; "soft focus" cameras are purposely given large amounts of spherical aberration.

Coma, astigmatism, curvature of field and distortion only afflict images away from the optical axis, and consequently they only

FIG. 3.

Spherical Aberration.

FIG. 4.

Coma.

appear in systems working with an appreciable field, *e.g.*, camera lenses, telescopic spectacles.

Coma was so called owing to the fact that a star image afflicted with coma was thought to resemble a head of flowing hair (Gr. *Κομή*); the word comet has the same derivation for the same reason. When rays pass obliquely through a simple lens the rays *a* and *b* (see Fig. 4) come to a focus on one side of the central ray *c*. The amount of coma may be measured by the distance *pq*. Coma, like spherical aberration, grows as the square of the lens aperture, but it also grows directly with the size of the field. There can be no coma at the centre of a field of a centred system, nor can there be any if the aperture be very small. That is to say, in telescopic spectacles there would be no possibility of spherical aberration if the patient's pupil were very small in diameter, and no possibility of coma if in addition, the field of vision were reduced to at most a few degrees!

Astigmatism, the most familiar, probably, of the primary aberrations, owing to its connexion with ophthalmic work, causes rays from one diameter of a lens to come to a different focus from those in other diameters, giving the same effect, in fact, as a spherocylinder. The rays are disposed so that two foci are formed, one being tangential to the field, the other radial. These foci are generally known as the sagittal and tangential foci respectively

(see Fig. 5.) The aberration called astigmatism in an ordinary lens-system differs from the familiar astigmatism of the eye in that it is zero on the axis and increases uniformly in every direction towards the edge of the field. The effect of this type of astigmatism is that *towards the outer parts of the field* point-images become elongated, either radially or tangentially to the field, as shown in Fig. 5. Astigmatism is measured by the separation between the sagittal and tangential foci S and T respectively (see Fig. 5.) Astigmatism in small amounts will not actually form linear images of point sources, but will elongate them; straight lines will be sharp in one meridian of the field at one of the astigmatic foci, and fuzzy in the meridian at right angles to it. In a mean meridian an average sharpness will exist. Astigmatism grows with the

FIG. 5.

square of the aperture and the square of the field. That is to say, that it will grow rapidly with the increase of either. With small apertures and small fields it will be negligible. It is evident that astigmatism induces a certain curvature of field since the best compromise focus in the presence of astigmatism is mid-way between the sagittal and tangential foci.

Petzval curvature also grows with the square of the lens aperture and the square of the field. It does not affect the definition of images, but flat objects are rendered as curved images; flat walls appear concave or convex; the images towards the edge of the field are nearer to, or further from, the lens system than the axial image. Provided the difference of focus between the edge and centre of the field is within the observer's range of accommodation, he is able to see all objects in the field clearly defined, but the effect is not agreeable. If astigmatism as well as Petzval curvature is present the curvature of field will be modified. The position of the best focus in these circumstances is a debatable question, and its selection depends on the discretion of the designer in view of the nature and use of the system.

Distortion is another aberration which does not affect the definition of the image. It merely displaces an image from its correct position, towards or away from the axis; it will cause a

square object to appear barrel shaped or pin-cushion shaped. This effect is unpleasant. Distortion varies directly with the aperture but grows with the third power of the size of the field. A small reduction of the field will greatly lessen the distortion.

In addition to varying the apertures and field of a lens system, there are two important methods varying these oblique aberrations namely, by redistributing the curvatures, called "bending" the lenses, and by varying the position and size of the entrance pupil and exit pupil; the position and size of the entrance pupil controls that of the exit pupil, since one is an image of the other.

There are two ways of regarding the entrance pupil of a Galilean telescope: following the custom with ordinary telescopes it may

FIG. 6a.

be considered to be the cell of the objective (see Fig. 6a) in which case the exit pupil will be virtual, falling to the left of the eye-lens. This, of course, is an impossible position for the patient's eye. As it is the observer's own pupil which ultimately limits the pencils received from the system it is more reasonable to look upon the entrance pupil as the image of the exit pupil, the latter being taken as the observer's own pupil. It is not practicable for the pupil of the eye to be situated at a point less than 15 mm. from the eye-lens of the Galilean telescope, owing to the protrusion of eyelids and lashes beyond the cornea. We can accept 15 mm., therefore, as being the closest possible position of the exit pupil. Tracing suitable rays back through the system we find a virtual entrance pupil falling somewhere behind the exit pupil (see Fig. 6b). It should be noticed that the enforced position of this exit pupil necessitates very eccentric passage of the oblique rays of a large field through the system, an undesirable but equally unavoidable state of affairs. Here again we find that the designer is severely restricted. One of his most valuable means of controlling the aberrations is entirely barred; he is bound to accept an unfavourable position of the exit pupil and to do what he can by "bending"

the objective and eye-lens. He has no less than six aberrations to correct with only three degrees of freedom—the bending of each component and the choice of the relative dispersions of the glasses. His task would clearly be impossible were it not for one or two facts that have not yet been considered.

The pupil of the eye in average daylight does not exceed 4 mm. in diameter. This aperture of a parallel pencil at the eye implies with $\times 1.8$ magnification an aperture of about 1.8×4 or 7.3 mm. at the objective for individual pencils of light. The spherical aberration arising at this aperture, though exceeding the fine tolerances set for first class instruments, is unlikely to be really objectionable to the average wearer of telescopic spectacles. The

FIG. 6b.

axial chromatic aberration, too, will not be appreciable. The oblique aberrations, chromatic difference of magnification, coma, astigmatism, curvature of field and distortion remain to be corrected as far as possible by choice of glass and bending of the components.

Frequent reference has been made to "bending" of lenses. It is well known that a lens of given power can assume various shapes, plano-spherical, bi-spherical or meniscus, and that these forms can be mounted either way round in the instrument to which they may belong. It should be strongly emphasised that the shape of a lens has a very marked effect on all the aberrations.

It has already been shown that the powers and separation of the eye-lens and objective, and the position of the exit pupil are fixed within very narrow limits. The designer can still decide whether the lenses shall be simple or compound. The lightness of weight required rather prohibits the possibility of a doublet objective. A cemented eye-lens is possible and it must be decided whether the additional advantage gained justifies the increase in weight and expense. The chief benefit would fall to the chromatic difference of magnification; although the other aberrations would benefit to some very appreciable extent.

Whether or not simple lenses are selected, the chromatic dispersion of the objective, and the other aberrations arising, have to be balanced against those of the eye-lens. The choice of glasses for objective and eye-lens are of vital importance since the degree of freedom from colour in the image entirely depends upon this. In Fig. 1*b* it will be seen that a pencil of light entering the objective contracts very considerably before it meets the eye-lens; the objective is therefore working at a greater aperture than the eye-lens. Further, owing to the separation of the components the blue and red rays emerging from the uncorrected objective have widely diverged by the time they strike the eye-lens (see Fig. 7). The objective, if achromatism of magnification is to be obtained, needs

FIG. 7.

to be made of glass of very much lower dispersion than the eye-lens. Within the last 20 years a glass of lower dispersion than that of the crown glasses previously made has been produced. Using this new glass, called fluor-crown, in the objective and a glass of high dispersion in the eye-lens, it is possible to design telescopic spectacles having a tolerable degree of chromatic correction with two simple lenses.

As regards the indices of the glasses, a low refractive index in the positive objective and a high one in the negative eye-lens helps the curvature of field and astigmatism very considerably. It is a condition for freedom from astigmatism and curvature of field that

$$\frac{1}{F_1 \mu_1} + \frac{1}{F_2 \mu_2} = 0.$$

This equation is independent of the separation of the components of focal length F_1 and F_2 and refractive index μ_1 and μ_2 . In order that this equation may approach zero F_1 and F_2 must clearly be of opposite sign, since μ_1 and μ_2 are inevitably positive. Further, if F_1 is larger than F_2 , then μ_1 must be smaller than μ_2 , in the same proportion. The construction of Galilean spectacles is therefore favourable. F_1 and F_2 are of opposite sign, and μ_1 of the objective is less than μ_2 , F_1 the focal length of the objective being greater than F_2 . This last discussion shows very clearly that the Galilean telescope, apart from considerations of compactness and lightness of weight, is much more suitable than the all positive

form. With finite and positive values of μ_1 and μ_2 , also F_1 and F_2 , the equation given above could not possibly approach zero. Very fortunately a glass of high dispersion also means one of high refractive index. The *most* favourable glasses for the eye-lens,

FIG. 8.

Bending objective effect on aberration in a particular case.

having highest dispersion and refractive indices, cannot be used because of their poor durability and low transmission of light.

Having selected the most favourable glasses, it only remains to find the best shapes of the two lenses. The simplest way of doing this is to trace suitable rays from the nearest practicable exit pupil through the system. By choosing three shapes of eye-lens and three shapes of objectives, a set of curves can be obtained expressing the change of the various aberrations relatively to the "bendings" of the lenses. It is very unfortunate that the aberrations vary at differing rates, and often oppositely. In Fig. 8 is shown a typical set of curves indicating the effect of bending an objective in a particular telescopic spectacle. It will be noticed that none of the aberrations indicated approach their minima together,

the coma is still falling when the curvature reaches a minimum. Also it should be noticed that the curvature, for instance, never does reach zero, neither does the distortion. The coma appears to be approaching a zero value, but as the curvature and distortion are growing very rapidly it would be useless to select the minimum coma "bending" even if it reached zero. A small amount of coma, probably unnoticeable by the average user, is much more tolerable than very heavy distortion and curvature. The designer must survey the whole series of curves he obtains, and knowing the relative seriousness of the various aberrations, he must choose those bendings of eye-lens and objective which seem to achieve the best compromise.

In a particular design it may quite possibly happen by good chance that the minima of the various aberrations occur very close to each other. If this is not so a little judicious variation of magnification, scale, separations, lens thicknesses and glasses may help appreciably after the best possible combination of bending has been chosen. The opportunities of such variation will, of course, be greater if the eye-lens is a cemented doublet, since a doublet consists of three curves, two kinds of glass and two thicknesses of lenses, instead of the two curves, one glass and one thickness of a simple lens. The doublet lens may be uncemented, in which case there will be further possibilities of varying the inside curves independently, also the air-gap between the units; in a cemented lens the inside curves are necessarily equal and the air-gap zero. It is, however, undesirable to have the components uncemented. It not only necessitates a more complicated mounting, adding weight to the spectacles, but it also lessens quite perceptibly both the amount of light and, what is really more important in these spectacles, the contrast in the image. Anyone who has done a little experimental photography knows the marked difference between the images produced by a lens consisting of a number of separated components, and by a single or cemented lens of the same focal length. The more complex lens may certainly give the better definition in the outer parts of the field, but it will not give the contrast, owing to loss of light at glass-air surfaces, and especially to internal reflections between the components producing a weak haze of what are really out of focus secondary images of the objects being photographed.

By following the methods very briefly indicated telescopic spectacles of a very respectable quality can be made for myopia, emmetropia and hypermetropia, also for reading. Myopic spectacles for distance vision have to be designed so that light entering the spectacles emerges from the eye-lens with the required degree of divergence corresponding to the myopia. Emmetropic spectacles for distance vision are pure telescopes, parallel light

entering and leaving the system. Spectacles for hypermetropia have to be provided with a positive power, so that parallel entering light emerges with a convergence corresponding to the hypermetropia it is required to correct.

Separate spectacles have to be provided for reading and distance wear.* This is rendered necessary because of the magnification of the spectacles; whereas 4D. of accommodation is normally required to read at 10 inches, something like 10D. of accommodation is required with the magnifying spectacles if the correction is placed behind the telescopic spectacle. As it is very inadvisable and frequently quite impossible for the wearer to exert this degree of accommodation it is necessary to supply him with special spectacles for reading. Another reason for the necessity of providing separate spectacles for reading and distance is that it is most important for the wearer to look axially through the system.* The P.D. and the angling of the frames has therefore to be different for different working distances. When reading spectacles are being specially designed, calculations must be made for light diverging from an object at the working distance. Strictly speaking a slightly different shape of the eye-lens and objective is required for every different condition of entering and emerging light. In practice it is good enough to have a series of spectacles, one for emmetropia, and perhaps one at every 10D. of ametropia. Intermediate degrees of ametropia can be corrected by giving the additional correction to the eye-lens or in a thin separate lens mounted over the eye-lens. It may or may not be found necessary to modify the designs for reading.

The foregoing discussion may possibly lead one to suppose that the telescopic spectacles are still very imperfect systems. Judged by the standard of first class photographic lenses, for instance, they certainly are not likely to be so good. But it must be realised that while the old telescopic spectacles were hopeless, a first class standard is fortunately unnecessary. The average untrained observer is not at all critical of definition provided it is moderately good. Moreover, the majority of wearers of these spectacles are incapable of critical observation owing to their own poor acuity and feebleness of vision. Such spectacles provided with a simple eye-lens are thought by many to be sufficiently good, if they be designed with care making the best use of the limited opportunities afforded.

At the beginning of the paper it was stated that surgeons had ceased to recommend telescopic spectacles to any except the excessively myopic, because the spectacles for emmetropia and hypermetropia were so poor. At the present time one firm (Theodore Hamblin, Ltd.) reports that it is supplying very many

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more telescopic spectacles for patients who are approximately emmetropic than for those who are highly myopic. Patients with very poor vision are deriving benefit which fully compensates the inevitably greater weight of these spectacles. This fact seems to be ample proof that even if the spectacles are not perfect, yet they have been so greatly improved in recent years that now hypermetropic and emmetropic spectacles can be of valuable assistance. A further and more convincing indication of the practical value of telescopic spectacles is the frequent and successful use made of them by surgeons whose unaided vision is normally acute.

The practical adaptation of conditions necessary to obtain the best result in the use of telescopic spectacles may be a matter of considerable importance, as is shown by the following case, for the details of which I am indebted to Dr. H. W. Buttery. In it a simple manoeuvre led to an extremely valuable result.

The patient, an intelligent youth aged 18 years, used such spectacles for all near work, his vision being very defective as a result of some degree of microphthalmos and nystagmus. By this means he was able to read with ease and his progress was such that he was working for the entrance examination of a university. But he was grossly handicapped in mathematics, especially geometry, where he seemed quite unable to grasp the construction of figures. This affected him not only in his work but in his outlook on life on account of his inability to understand a wide sphere of common knowledge and interest. In other directions he felt no disability. It was obvious that the principal cause of his difficulty was the small field given him by his spectacles so that he was unable to obtain a conception of the figures and problems as a whole. Accordingly the procedure was adopted of getting him to learn the subject from figures much reduced in size but kept to scale.

By trial it was found that if each of the problems of Euclid were so reduced in size as to lie within one square inch he was able to get the whole figure within his field of vision. The legend of each problem was condensed into the adjacent square inch, so that with the least movement he was able to see the figure as a whole and the attached legend. He readily took to this method and made great advance in geometry and algebra, being able not only to see the figure but to write out at length over the page the proposition involved. As a wider issue this advance seemed to make him feel much less handicapped in life and better able to meet his fellows and converse with them in a normal manner. He was a very sensitive youth but this simple aid to his vision produced a most striking improvement in his mental outlook.

I have to acknowledge my indebtedness to Miss H. G. Conrady, of Messrs. Theodore Hamblin, Ltd., for much assistance in the preparation of this paper.