

AN UNFAMILIAR ANOMALY OF VISION AND ITS RELATION TO CERTAIN OPTICAL INSTRUMENTS

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Any optical instrument provided with a prism erecting system should satisfy the condition of complete erection of the image, that is, vertical and horizontal lines of the object should appear vertical and horizontal in the image within certain small limits. One one occasion the writer attempted to judge the character of this adjustment of a field glass by employing a well known method often used for making an approximate determination of magnifying power, viz., the method of simultaneous observation of an object by one eye through the telescope and by the other without the telescope. Choosing in this case a flag staff as the most suitable object, the two images did not appear parallel and the glass was condemned as imperfectly adjusted. Subsequent examination with the apparatus usually employed for the purpose proved that the adjustment was satisfactory. Curiosity aroused, the former method was then applied to a telescope without a prism erecting system and again the two images were found to be inclined to each other. Tests were next made on nearly all of the Scientific Staff of the Bausch & Lomb Optical Company and without exception all observed the same effect.

Reference to the literature disclosed the fact that the phenomenon is well known to physiological opticians but the knowledge seems not to have spread far out of their ranks. The subject was very thoroughly investigated by A. W. Volkman in 1864, whose measurements are extensively quoted by Helmholtz in his *Handbook of Physiological Optics*.

It appears, according to Volkman, Helmholtz and other more recent writers, that a horizontal line appears horizontal to both eyes in the great majority of cases but that a vertical line does

not in general appear vertical to either eye. In single binocular vision the two images are fused into a single vertical line but if the fusion be destroyed by any means so that the two images are seen separately they appear to converge downwards or upwards according as the convergence of the eyes is less or more than is required for fusion. Consideration is limited in this discussion to subjects who are not afflicted with pathologic cyclophoria nor with extraordinary degrees of astigmatism.

In addition to the method described of looking at a vertical line through a telescope with one eye and alongside the telescope with the other, there are other methods of producing the two separate images necessary for the observation. One such method consists in inserting a prism before one eye with base in, that is, with the base turned toward the nose. If placed before the eye with base out the eyes will generally converge to accomplish fusion of the images unless the deviation of the prism be so great as to make observation difficult for other reasons. If instead of a single prism a bi-prism be placed before the one eye with edge vertical, three images of a single vertical line will be seen which cannot all be fused into a single one. Again, holding a pencil vertically in the line of sight look at the wall beyond it. Two images of the pencil will be seen. Under these circumstances the two images of the pencil will appear to diverge upwards.

It is significant that the amount of the divergence is generally about equal to the angle subtended at the ground by the interpupillary distance. It is equally significant that if, in the experiment with the pencil, instead of holding it vertical the top is tipped away from the observer so that it lies approximately at the inclination of a book in reading, the two images appear parallel. These facts lead to the conclusion that the phenomenon may be due to some effect of experience.

Now if the effect is due to some process of education it seems that children, whose experience in life has not been so extensive, should not exhibit it or if they do that it should be to a less degree. Six children were tested using the telescope and the pencil tests as described. Five, ranging from nine to twelve years of age, were certain they saw the two images as parallel. One girl of thirteen

was uncertain thinking that at times she saw them parallel and at other times as diverging slightly. It is recognized that in a purely qualitative test, such as this, consideration must be given to the lack of training of children's powers of observation. In order to test to some degree the value of their observation, however several pairs of lines were drawn, each pair on a separate sheet of paper, some pairs being parallel while others were of varying degrees of divergence. The children tested had no hesitation in detecting divergence of considerably less than 1° which is less than half the usual divergence seen by an adult. More precise tests on a greater number of subjects are contemplated. The experiment, incomplete as it is, tends to establish the truth of the education hypothesis.

As to the nature of the product of this hypothetical educational process, it must be one of two things; either, as suggested by Stevens, there comes to be established a slight cyclophoria which is manifest when the eyes are at rest but which is overcome whenever single binocular vision is obtained, or else it is purely a matter of interpretation.

Most of our work is done at comparatively short ranges and calls for continued effort on the part of the muscles which produce convergence. So much is this so that most of us, while possessing strong power of convergence, have practically lost the power to diverge the lines of sight. Very young children and savages possess both to about equal degree. It is worth noting in this connection that single binocular vision is one of the latest developments in the process of evolution. The prolonged tension to which the muscles of the eye are subjected possibly results in a position of the eyeball which, while abnormal with respect to condition at birth, let us say, is normal in the sense that it is peculiar to practically all civilized adults. The cyclophoria hypothesis may find support in the fact that the phenomenon under discussion varies in its character and amount if the head is tipped forward and the eyeballs rolled upward. A position of the head can generally be found which makes the images parallel but that position is not by any means the natural one.

On the other hand, there are two experiments which seem to cast doubt upon the validity of the cyclophoria hypothesis. If a distant vertical line be regarded with both eyes and the head in normal position, of course a single line is seen. Now by quickly interposing a prism, of about four prism dioptries preferably, with its base turned toward the nose, a double line is immediately seen, the lines being inclined to each other. If fusion can be accomplished they merge into a single line. If by voluntary effort the eyes can be held in their original position and the prism be suddenly withdrawn the line immediately appears single. On the basis of the cyclophoria hypothesis it seems necessary to assume that the introduction of the prism and the consequent destruction of fusion permits the eyes to assume a position of rest and that to get single binocular vision again it must be assumed that they rotate slightly on their anterior-posterior axes. With full recognition of the possibilities of motor responses to stimuli which have not yet reached the brain it seems impossible to believe that the brain does not ultimately recognize the stimulus especially if watching for it. It seems reasonable, therefore, in this experiment, to expect that the two lines first seen when the prism is interposed before the eye would appear parallel and that they would ultimately take a position of upward divergence. Conversely, when the prism is suddenly removed from the eye we should expect to see two crossed lines which by rotation about their point of intersection ultimately fused into one. Furthermore, it does not appear entirely unreasonable to expect that the mutual rotation of the image could be detected although this point is more open to question. A little practice is required before the image can be seen without momentary confusion, but after a little experience the single or the double image can be instantly recognized and the change from one to the other appears to occur instantaneously.

Again, regard two vertical parallel lines; hold a pencil vertical before the eyes and adjust distances so that the pencil appears tangent to one of the lines when seen by the right eye alone and tangent to the other line when seen by the left eye alone. Now fix on the plane of the two parallel vertical lines. The two parallel

lines appear parallel but the two pencil images appear to diverge upwards. Inasmuch as the lines on the back-ground appear single, vertical, and parallel, it must be assumed that the eyes have assumed the hypothecated position for single binocular vision, and if the phenomenon with which we are concerned is due to a departure of the eyes from this position when the required stimulus is absent, that we have now supplied the stimulus which should bring the eyes into working position. Under these conditions the two pencil images should appear to be parallel, but they do not and it seems impossible, therefore, that the phenomenon can be ascribed to cyclophoria. It seems much easier to believe that it is a matter of interpretation in the same class, possibly, as the interpretation of the inverted images of our retinas.

The phenomenon has a direct bearing on all optical instruments which employ a prism system for erecting the image such as prism binoculars, binocular microscopes, stereoscopic range finders, etc. In any of these instruments, unless single binocular vision is obtained, there is the impression that the instrument is out of adjustment on account of this apparent divergence of lines which should appear parallel. Furthermore, it is quite unsafe to attempt to discover by means of the expedient described above whether the image formed by a prism telescope is completely erected.

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