ART. XXXV.—*Some experiments and inferences in regard to Binocular Vision*; by Prof. WILLIAM B. ROGERS.

IN the theory of binocular vision which has been so ably expounded by Sir David Brewster, Brücke, and others, it is contended that no part of an object is seen single and distinctly, but that to which the optic axes are for the moment directed, and that "the unity of the perception is obtained by the rapid survey which the eyes take of every part of the object." According to this view our perception of an object in its solidity and relief, instead of being the simple and direct result of the pictures formed at any one moment in the two eyes, is acquired by a cumulative process, in which the optic axes are successively converged upon every point of the object within view.

In an experimental discussion of some points in binocular vision published in the *Am. Journ. of Science* several years ago,* I was led to conclude that the phenomena of the stereoscopic resultant do not necessarily or even usually conform to these conditions, and that "the perception of a perspective resultant line or of a physical line in the same attitude does not require the successive convergence of the axes to *every point*." The grounds of this conclusion were,—first that the perspectiveness of the resultant although not perceived when the axes are steadily maintained at any one convergence, appears as soon as they are allowed sufficient freedom of motion to *unite a few contiguous points* of the component lines, and that it then effects the whole extent of the resultant; and—second that the resultant presents a perspective attitude even when the component lines, instead of being united into one, are brought together so as to intersect at a small angle, *each of the intersecting lines in this case appearing in relief*.

Satisfied from these considerations that the perceived single-ness and relief of the resultant are to be ascribed rather to a *process of suggestion* than to the exhaustive binocular survey which has been supposed necessary, I was led to the opinion that, while some change of direction and convergence of the axes is needed for the effect, the successive view of a few contiguous points is all that is required to bring the suggestive action into play and to give rise to the full perception of the position and relief of the resultant.

In this view while rejecting the theory of successive vision in the form in which it has been propounded, I still considered some degree of motion of the axes as one of the steps by which we obtain the perception of the binocular resultant.

The following experiments, intended still further to test the theory of the successive combination of corresponding points

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in binocular vision, are believed to be in part new, and are in part modified repetitions of experiments already described by Profs. Wheatstone and Dove. They offer what seems to be decisive proof that such a successive combination of pictures point by point, however it may enter in many cases into the complex process of vision, *cannot be regarded as an essential condition to the singleness and perspectiveness of the binocular perception.*

1. Let a brilliant line, held in a perspective position at a convenient distance midway between the eyes, be regarded intently for a few seconds so as to produce a lasting impression on the retinae. On turning the eyes towards a blank wall or screen the subjective impression will be seen projected against it and having the same perspective altitude as the original line. If then one eye be closed the line will appear to subside into the surface of the screen taking an inclined position corresponding to the optical projection of the original line as seen by the unclosed eye and therefore corresponding to the image formed in that eye. By opening and closing the eyes alternately, and finally directing both to the screen we are able to see the two oblique lines corresponding to these projections and their binocular resultant corresponding to the original object.

2. Let two slightly inclined luminous lines formed by narrow slits in a strip of black card-board be combined into a perspective resultant either with or without a stereoscope. Looking at this for a few seconds so as to induce the reverse ocular spectrum, and then directing the eyes towards the opposite wall of the apartment, *a single spectrum will be observed having the attitude and relief of the original binocular resultant.*

As a strong illumination of the lines is necessary to bring out the most striking effect, the card-board should be held between the eyes and some brilliantly white surface, as the globe of a solar lamp or a strongly illuminated cloud, care being taken to prevent the entrance of extraneous light.

3. Using the same arrangement, let the luminous lines be regarded in succession each by the corresponding eye, the other eye being shaded so that no direct binocular combination can be formed. On looking toward the wall it will be seen that *the two subjective images unite to form a single spectral line having the same relief as if the lines had been directly combined with or without the stereoscope.*

While the perspective image continues distinctly visible, let either eye be closed the other being still directed towards the wall. The image will instantly lose its relief and take its position on the plane of the wall as an inclined line corresponding to the subjective image in the eye which has remained open. When the subjective impressions have been sufficiently strong, it is easy to alternate these effects by projecting first the picture

proper to the right eye and then that of the left on the plane of the wall, with their respective contrary inclinations. On then looking with both eyes we see the resultant image instantly start forth in its perspective altitude.

It is hardly necessary to say that in order to obtain these effects satisfactorily even with lines very strongly illuminated, the observer should have some practice in experiments on subjective vision. *In these circumstances, however, I have found the results to be perfectly certain and uniform.*

The conditions of the experiments are obviously such as to exclude all opportunity of a *shifting of the image on the retina*. Such a shifting however is essential to that successive combination of pairs of points in the two images which on the theory of Brewster is required for the production of the single perspective resultant. Hence according to this theory the resultant spectrum in these experiments, instead of being a single line in a perspective position, ought to present the form of two lines inclined or crossing, situated in the plane of the wall without projection or relief.

In reference to the first two experiments it might perhaps be maintained that as the perspectiveness of the original line or resultant on which the eyes were converged formed part of the direct perception in the first stage of the experiment, it would be likely through association to be included also in the spectral or subjective perception. But this consideration, which at best does not impress me as of much weight, is entirely inapplicable to the conditions of the last experiment, where the eyes are in the first place impressed *in succession* with their respective images, and where yet when they are together directed to the wall, *the perspective single resultant at once springs into view.*

4. Without resorting to these troublesome efforts of subjective vision the following is a simple proof that pictures *successively* impressed on the respective eyes are sufficient for the stereoscopic effect. Let a screen be made to vibrate or revolve somewhat rapidly between the eyes and the twin pictures of a stereoscope, so as alternately to expose and cover each, *completely excluding the simultaneous vision of the two.* The stereoscopic relief will be as apparent in these conditions as when the moving screen is withdrawn.

Here there is no opportunity for the combination of pairs of corresponding points in the two diagrams by the simultaneous convergence of the optic axes through them, but at each moment the actual picture in the one eye, and the retained impression in the other, form the elements of the perspective resultant which we perceive.

5. The ingenious experiments described by Prof. Dove many years ago in which the stereoscopic effect was obtained by the

momentary illumination of the electric flash, furnish a further and most powerful argument against the theory of successive binocular combination here referred to.

In repeating these I have found great advantage in using one of Ritchie's improved Ruhmkorff coils having a coated jar included in the outer circuit, the intensely brilliant spark of which can be made to throw its light upon the object viewed in any direction or at any interval that may be desired.

When a twin-diagram of any simple geometrical solid was placed in the stereoscope and viewed by this momentary light it was found to exhibit the perspective resultant in most cases with a single spark, and it never failed to present it in perfection with a succession of sparks even when they followed each other slowly.

A large circular disc of brass, marked with the usual concentric striæ, was placed in a position to catch the illumination and produce the peculiar intersecting lines of reflected light. At each spark the bright resultant line due to the binocular union of these intersecting lines was seen penetrating the disc and extending in a steep angle beyond and in front of it.

As, according to Wheatstone, the duration of an electric spark is less than one-millionth of a second, it can hardly be supposed that in either of these experiments the eyes have time to make the successive changes of direction required, by the theory, for the singleness and relief of the observed resultant. Not less at variance with this theory is the familiar fact that the illumination of a single flash of lightning is sufficient to give us a clear perception of the forms and positions of objects to which the eyes are for the moment directed. So the long straight spark of one of Geissler's narrow vacuum tubes, glowing for an instant in a dark room, impresses a precise perception of the altitude and place of the tube and its included line of light, and even their regular path of the long spark through the air produces a distinct perception single and faithful to its devious directions.

We may therefore conclude—*first*, that the perception of an object in its proper relief, or that of the perspective resultant through binocular combination in a stereoscope, or otherwise, may and most usually does arise, by *direct suggestion* from the two pictures impressed, without requiring the successive combination of corresponding points;—*and second*, that for the singleness of the resultant perception, it is not necessary that the images should fall on what are called corresponding parts of the two retinas.

The condition of single vision in such cases seems to be simply this, that the pictures in the two eyes shall be such and so placed as to be identical with the pictures which the real object would make at a given distance and in a given altitude before the eyes.