SUPPRESSION THEORY OF BINOCULAR VISION*

BY

H. ASHER

Physiology Department, University of Birmingham

The problem of how an object may be perceived as single when it is viewed with both eyes is one which is not yet solved. In the past, du Tour (1760) and other scientists found that there was no fusion of the two images, but that always one of a pair of corresponding points suppressed the other. Another view was that of Heine (1900), who held that there was a single common centre which could be stimulated simultaneously by pathways originating from the two retinas. A third view is that of Sherrington (1906), who held that a single sensation arose from the fusion of two sensations which originated separately, one from each visual pathway.

Du Tour's theory was put forward before there was any knowledge of depth perception due to disparity of the retinal images. It was considered by both Wheatstone (1838) and Panum (1858), but was thought to be incompatible with data from experiments with stereoscopes, and not to fit in with the idea of disparity as a clue to depth perception. It is proposed here to reconsider du Tour's opinion in relation to the problem of depth perception.

Method of Viewing the Diagrams.—The diagrams shown in this paper should be combined as in a stereoscope. The most convenient way to do this is as follows:

The observer places his elbows and the diagrams on the table, holds in each hand a 3-dioptre convex lens which he places close up to his eyes, and views through their inner halves the two diagrams to be combined. Sideways adjustment of the lens position will aid combination. Since the images will be near infinity, the accommodation should be relaxed and the normal distance spectacle correction, if any, should be worn.

Experiments

Experiment 1 (Fig. 1).—The left eye views the lady, the right eye views the fire, and in the combined picture the lady is seen cooking over the fire. The black frame is seen by both eyes. Although the lady and the fire are each seen by one eye only, they appear equally as black as the frame which is seen by both eyes. Thus the portions of white ground corresponding to the lady and the fire are completely inhibited.

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**Experiment 2** (Fig. 2).—The two pictures show left-eye and right-eye views of a small model archway. Notice that the right eye can see through the archway but the left eye cannot. When the two pictures are combined, the depth effect emerges. Also the appearance of the archway will be either that of the right-eye view or that of the left-eye view. The scene will not appear as a mixture of the two views, although the two may alternate. Thus one bit of archway always suppresses the other.

![Figure 2](image-url)

*Fig. 2.*—Experiment 2 (after Wheatstone, 1838). Shows the suppression which occurs with disparity of the retinal images. The appearance of the archway indicates which eye is dominant for this part of the picture.

**Experiment 3** (Fig. 3, Wheatstone’s cross).—Left-eye and right-eye views are shown of a cross consisting of a thin vertical bar and a thick horizontal bar. The cross is in front of the observer, below the level of his eyes, and so placed that the horizontal member lies in the vertical plane containing the right visual axis. A dot is placed above the line in the right-hand picture. When the top of each vertical line is fixated, the combined appearance shows the following features:

1. A vivid depth effect with the thick horizontal bar apparently passing through the paper.
2. A vertical line which may be thin, or thick, or may alternate between thick and thin.
3. A dot which always appears above the vertical line.

![Figure 3](image-url)

*Fig. 3.*—Experiment 3 (Wheatstone’s cross, 1838).

**Experiment 4** (Fig. 4a, b, and c).—To combine the diagrams of Fig. 4(a) each eye should fixate the disk. The line and the square then fall on disparate areas and appear to be well separated from each other.

In Fig. 4(b), when each eye fixates the lower disk, then the upper disks fall on disparate areas. Now a single upper disk is seen to be displaced apparently towards the observer.

In Fig. 4(c) the lower disks are again fixated, and as in Fig. 4(b) a single upper disk is seen to be displaced apparently towards the observer. In the combined view, the dot appears in the same position in relation to the lower disk as in the right-hand diagram.
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Fig. 4.—Experiment 4. (a) When the disks are fixated, the square and the line appear to be separated because they do not fall on corresponding points. (b) When the two lower disks are fixated, the upper disks fall on disparate areas, but they are nevertheless seen as single. (c) The lower disks are fixated, and a single upper disk is seen. The position of the dot in the combined view is the same as in the right-eye view. The correspondence of elements in this region has not changed.

Experiment 5 (Fig. 5).—When these two diagrams are combined the disks appear disposed in depth as before. If the upper disks are fixated then in the mental picture the single upper disk has a cross above and below it with a dot to the right. If the eyes are now moved down to fixate the lower disk, the crosses take up the position illustrated in the combined view, and appear to be in line with the dot.

Fig. 5.—Experiment 5. The eyes fixate first the upper disks, then the lower ones. The movement of the crosses is immediately apparent, and is such as to show that correspondence is maintained. The left upper disk may or may not appear in the combined view.

Experiment 6 (Fig. 6).—The eyes are directed so as to cause the centre of the left upper disk to fall on the fixation point of the left eye, while the small dot falls on the fixation point of the right eye. An experienced observer can achieve this without difficulty, and when this position is attained it is easily maintained because the lower disks now fall on corresponding points, so that the eyes are to some extent locked in this position. The appearance is now as shown in the figure. The black dot is distinguished from the black disk on which it is superimposed because it carries with it some of its own white surround. The gaze is now directed downwards to fixate the apparently single lower disk. This is very easily done by a simple downward movement of both eyes without any change in convergence. The mental picture now changes to that shown in Fig. 6; the disk which before surrounded the dot is seen to disappear from it, and the dot itself does not move.

Fig. 6.—Experiment 6. The left eye fixates the upper disk and the right eye fixates the dot. Both upper disks are seen, that from the left eye appearing to be superimposed upon the dot. The eyes now move down to fixate the lower disks, whereupon the upper disk seen by the left eye fades out. There is no lateral movement of this disk.

It is very instructive to repeat this experiment with a slow downward movement of the eyes, when the disk will be seen to fade away gradually. When careful attention is paid
to the presence of this disk it can be dimly perceived even in the lowermost eye position when the lower disks are fixated.

It is very clearly observed that the disk fades out slowly, and the emergence of the vivid stereoscopic appearance is likewise quite unmistakable. The precise time relation between these two processes is not easy to observe, but it would seem that the stereoscopic appearance is well established before the disk on the dot has faded out.

**Experiment 7** (Fig. 7).—The small dot is transferred to the left-hand picture. The left eye now fixates the dot, and the right eye fixates the upper disk; this brings the lower disks onto corresponding points and maintains the position stable. The appearance is as shown in the Figure. On transferring the gaze to the apparently single lower dot, the eyes execute a conjugate movement downwards and to the right without any change of convergence. The appearance may now be either that of (a) "left eye dominant" or that of (b) "right eye dominant". These are flat views of a three-dimensional mental picture; in each case the upper disk appears to be the nearer of the two.

![Image](https://i.imgur.com/3Q5Q5Q5.png)

**Fig. 7.**—Experiment 7. The left eye fixates the dot and the right eye fixates the upper disk. The upper disks now fall on disparate areas and are seen as double. The eyes now move down to fixate the lower disks. The upper disks continue to fall on disparate areas, but now they may be seen as single. Either of these two appearances is possible according to the dominance of the left or right eye: (a) shows left eye dominant, (b) shows right eye dominant.

**Experiment 8** (Fig. 8).—The two pictures shown in the Figure represent the left-eye and right-eye views of three spheres arranged in a vertical plane containing the left visual axis. Of the two top spheres the left eye can see only the near one which hides the hinder one from view. When the pictures are combined the three-dimensional scene is vividly reproduced.

![Image](https://i.imgur.com/5Q5Q5Q5.png)

**Fig. 8.**—Experiment 8. The eyes fixate the bottom disks. Two upper disks are perceived, one nearer and one further away than the bottom disk. To account for this by the fusion theory, the upper disk of the left eye would have to change its correspondence in two different directions simultaneously.
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**Experiment 9** (Fig. 9).—This is similar in essentials to Experiment 8, but many observers find it easier to perform and more striking.

![Fig. 9.—Experiment 9.](image)

**Experiment 10** (Fig. 10)

*Part 1.*—Each eye fixates the top of the left line of the pair. In the combined picture the apparent separation of the lines may be either that of the pair seen by the left eye or that of the pair seen by the right eye. These two appearances may alternate.

*Part 2* (*Panum's experiment*).—The ground of the left card is made red and that of the right card is made blue. It is observed that the space between the vertical lines may be seen in various ways:

- partly blue and partly red;
- blue;
- red;
- both blue and red simultaneously as if one were perceived through the other.

![Fig. 10.—Experiment 10 (after Panum, 1858).](image)

**Experiment 11** (Fig. 11).—Left-eye and right-eye views of a black disk are seen through a hoop. Two subsidiary marks are provided to ensure accurate fixation. With fixation steadily maintained on the black disk, careful attention being paid to the appearance of the hoop, the latter will be seen to assume one or other of the two forms illustrated.

If a point at 9 o'clock or 3 o'clock on the hoop is fixated, a single disk is *never* seen in the centre of the hoop. If the disk is seen as single it is always offset from the centre, and if it is seen as double the two disks are disposed one on each side of the centre.

![Fig. 11.—Experiment 11.](image)
Experiment 12 (Fig. 12)

Part 1. Hecht's experiment.—Red and green filters are arranged in a box as shown in the diagram (Fig. 12), and the eyes look through these filters at a 500-watt lamp which projects through a sheet of white cardboard. The lamp and the area of cardboard round it are seen by the right eye through the green filter and by the left eye through the red filter. The responses of observers vary somewhat, but typically three squares are seen, a yellow one in the centre where red and green fields overlap, a green one on the right, and a red one on the left.

Part 2. To show that the yellow appearance is not due to binocular mixture.—The experiment is repeated and when the yellow square in the centre is clearly perceived, the observer closes his left eye. Surprisingly, no change in colour is observed, although the white surface is now being seen through nothing but a green filter.

Part 3. To show that the yellow colour is caused by the brightness of the lamp affecting the view through green filter.—Still using the right eye only, the observer moves the box so that the lamp is in line with the red glass. Immediately the cardboard viewed through the green glass appears as a rich green; the change in colour is very striking.

(a) When both eyes are open, the colour appears yellow where the fields overlap.

(b) With the left eye closed, the field seen by the right eye through the green glass still appears yellow.

(c) The apparatus is now moved so that the lamp is still seen by the right eye, but through the red glass; the field seen through the green glass now appears truly green.

**Fig. 12.—Experiment 12.**
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**Discussion**

*Experiment 1.*—A perfectly normal picture is seen of a lady cooking over a stove. Since it is certain that the portions of white ground corresponding to lady and fire are completely suppressed, the experiment demonstrates that normal vision may occur while there is suppression in each eye. This result accords well with the theory of du Tour (1760) that one of a pair of corresponding points is always suppressed by the other.

If it is held that in normal vision there is some fusion or addition of impulses from corresponding points of the two retinae, then it must be supposed that the striking suppression shown in this experiment is an abnormal occurrence evoked by the particular experimental arrangement. That such an inhibitory mechanism could lie dormant and disused all one's life to emerge with full efficiency the first time that an experiment of this kind is performed, seems extremely unlikely.

*Experiment 2.*—When the two pictures of the small model archway are combined the images on the retinae of the observer are identical with those which would be there if he looked at the model under normal conditions. Furthermore an equivalent experiment may be performed by looking at a real model without a stereoscope (for this purpose a reel of selotape may conveniently be substituted for the archway); precisely the same result occurs.

This experiment demonstrates that suppression and the depth effect can occur together under normal conditions of vision.

*Experiment 3.*—Since the dot appears above the vertical line in the combined view, it is clear there has been no change in the correspondence of points in this region.

In the combined view the vertical member suffers rivalry and appears as either a thick or a thin line, showing that the vertical thin line of the left picture and the vertical thick line of the right picture both fall on corresponding points. Thus the combination of the two pictures and the emergence of the depth effect have caused no change in the correspondence of the retinal elements.

The fact that the depth effect can be seen at periods during the rivalry when the vertical line appears thin shows that it can occur during suppression, while the fact that it can be seen at periods during the rivalry when the vertical line appears thick shows that the depth effect can still exist when the disparity is so great as to cause diplopia. This accords with the results of Tschermak and Höefer (1903) and of Wright (1951).

Wheatstone (1838) used this experiment to argue that there was no fixed set of correspondences between points. Hering (1861) maintained that correspondence was rigidly maintained and that suppression of the vertical line of the right picture occurred, but he denied that there was a genuine stereoscopic effect!

*Experiment 4.*—(a) The combined picture consists of a single disk, above which are seen a line and a square well separated from each other. Here both square and line suppress the corresponding portions of white ground in the same way as did the lady and the fire of Fig. 1.

(b) This corresponds to Fig. 4(a) except that disks are substituted for the square and the line. From the usually accepted theory that the single upper disk which is perceived results from the "fusion" together of the upper disk on each retina, it must follow that there is a change in the correspondence of elements in this region.
(c) This indicates that there is no change in correspondence at any rate of those points which are situated just outside the right upper disk.

On the suppression theory the explanation will be that correspondence is rigidly maintained, and that a single upper disk is seen because one of the two is suppressed.

The Two Kinds of Suppression.—The first kind was illustrated by the lady and the fire of Fig. 1, and is characterized by the fact that the figure suppresses the ground. In the past the existence of this kind of suppression has been surprisingly neglected. Thus, supposing a patient under orthoptic treatment sees the whole of the parrot and of the cage, then normally it would be said that there is no suppression, although as we have seen, some white ground is completely suppressed in each eye. However, if, for example, part of the parrot appears to be missing, then it is usual to say that there is suppression. What has in fact happened is that the usual direction of the suppression has been reversed, so that now the ground suppresses the figure. This constitutes a second kind of suppression. Experiments show that in general both black and white in the neighbourhood of a contour possess an enhanced value which enables them to suppress whatever falls on the corresponding points of the other retina. Suppression of the second kind occurs when elements of ground possessing such enhanced powers seen by one eye suppress all or part of the figure seen by the other eye.

Role of the Two Kinds of Suppression.—Now, on the fusion theory these two kinds of suppression are mechanisms which are exercised only under artificial conditions, as when looking at dissimilar drawings in a stereoscope. On the suppression theory, each mechanism plays an important part in the normal visual process. Consider, for example, Fig. 4(b): here both kinds of suppression occur; firstly the upper disk seen by the right eye appears in the combined view to be completely black, having entirely suppressed the corresponding white ground; this kind of suppression eliminates the appearance of any intermediate hues such as grey, which would appear if any fusion occurred from corresponding points. Secondly, the upper disk seen by the left eye has been entirely suppressed because the white ground near the upper disk of the right picture possesses enhanced powers of suppression by virtue of its proximity to this disk. This kind of suppression eliminates the diplopia which would result if in each case the black disk suppressed the white ground. Now, although a stereoscope has been employed, the retinal images are just those which would be formed if black spheres suitably arranged in space were viewed with both eyes, and the mechanisms invoked are just those which will apply under normal conditions. In the example given above there were two quite distinct suppressions, namely suppression of ground and suppression of object, and these two separate suppressions are necessary to avoid the occurrence of intermediate hues and of diplopia respectively. In other cases there may be no clear distinction into object and ground, but whenever there is disparity of the image, to avoid the two defects mentioned, these same two distinct processes
of suppression must occur. This is perhaps best expressed by saying that whenever there is disparity of a contour, then the contour and the area adjoining it on both sides in the one eye will suppress the corresponding points in the other eye. If the area involved on either side of the suppressing contour is sufficient in extent, the disparate contour in the other eye will be suppressed, and single vision will result.

Experiment 5.—This is similar to Experiment 4(c), and shows that there is no change of correspondence of elements in the neighbourhood of either of the disks, and that correspondence is rigidly maintained.

Experiments 6 and 7.—In previous experiments the suppression of the upper disk of the left picture has been inferred from its failure to appear in the combined view. Here, during the slow downward movement of the eyes, this disk can be seen to fade out slowly, thus enabling the actual process of suppression to be witnessed as it occurs. The fusion theory anticipates a sideways movement of the disks towards each other, but no such movement is observed.

A Possible Objection.—It could be argued that as the upper disk of Fig. 6 gradually fades out, so the points which receive the image of this disk on the left retina change their correspondence one by one. Thus, with the eyes in the upper position, the upper black disk of the left picture would correspond with the dot and the surrounding white area in the right picture; then as the eyes are lowered, so the correspondences might change in such a way that when the lower disks are fixated, the upper black disk in the left picture would fall on retinal areas corresponding to those receiving the image of the upper black disk of the right picture. The faded disk would correspond to the condition when some of the points had changed their correspondences and others had not. Experiment 8 was designed to give evidence on this point.

Experiments 8 and 9.—On the fusion theory, to explain the nearness of the nearest disk, the upper disk of the left picture is supposed to fuse with the left upper disk of the right picture, and the retinal elements must be supposed to change their correspondence accordingly. Similarly, to explain the remoteness of the furthermost disk, the upper disk of the left picture now has to fuse with the right upper disk of the right picture, and again the retinal elements must be supposed to change their correspondence accordingly. Thus, to explain the apparent position in space of both upper disks, two sets of correspondences will have to exist simultaneously. It is scarcely conceivable that such a mechanism could exist, especially since a situation requiring this feat hardly ever occurs in real life.

On the suppression theory it is necessary only to suppose that the upper disk of the left picture is suppressed.

Experiment 10

Part 1.—This experiment is based on one described by Panum (1858). The fact that the apparent separation is that of either the left or the right pair obviously lends support to the suppression theory. The subsidiary marks assist the observation that the right line of either the left or the right diagram is suppressed.
Part 2.—Panum interpreted this result as disproving the suppression theory. He thought that since the vertical lines appeared widely separated the space between them must appear wholly of the colour of the left card, i.e., red. This rejection of the theory must be criticized on two grounds:

(i) On the suppression theory: if, say, the left line of each card is fixated, then in one eye the right-hand line will be suppressed; if the suppression occurs in the right eye the lines will appear widely spaced. The whole of the ground in between need not, however, appear entirely red, though clearly part of it must do so.

(ii) With shades of red and blue so chosen that now one and now the other predominates in the process of rivalry, it is most interesting to notice how well the two changes occur together. If the ground of the left card is made blue, and that of the right card red, then the ground in the combined picture will appear now mainly blue with the lines closely spaced, now motley with the lines still closely spaced, now motley but with the right-hand line seen double, and finally, as the innermost one fades, the ground becomes predominantly red.

Experiment II.—When the disk is fixated, the two alternative appearances of the hoop are clearly due to suppression either of the inner or of the outer halves of the circles. The disk may also appear in a circular hoop, and displaced either to the right or the left. This corresponds to suppression of both the disk and the hoop of one or the other picture.

With points fixated at 3 o’clock or 9 o’clock on the periphery, the disk appears to the left or right of the centre according as the disk of the right or the left picture is suppressed. If neither disk is suppressed, then two disks are seen, one on each side of the centre.

It is important to notice that the disk never appears in the centre of a circular hoop, as the fusion theory would lead one to expect.

It may happen that an observer seeing figures of this type may see the disk as displaced from the centre by an amount intermediate between the displacements in the two separate pictures. This finding appears at first sight to be opposed to the suppression theory, and Experiment II was designed to investigate this effect. The phenomenon always fails to appear when subsidiary marks are used to ensure accurate fixation, and the effect may accordingly be ascribed to failure to maintain fixation accurately.

Binocular Colour Mixture.—According to the suppression theory, one of a pair of corresponding points always suppresses the other, and it would consequently be anticipated that binocular mixtures of colours could not occur. Since, however, there is a considerable body of evidence to support the view that these mixtures can in fact be produced (Meyer, 1856; Trendelenburg, 1914; Hecht, 1928; Prentice, 1949; Hurvitch and Jameson, 1951), it is important to examine the evidence carefully.

If an attempt is made to combine two different colours in the stereoscope, the usual result is not fusion, but rivalry.

In the arrangement due to Meyer (1856), one eye sees a square of which the left half is yellow and the right half blue, while the right eye sees a red square. The yellow and blue remain distinct in the neighbourhood of the boundary, but further out, although there is much rivalry, some sort of mixture with red does appear to occur; the appearance, however, is peculiar, impossible to describe in words, and unlike uniocular mixtures.
It is suggested in these cases only one of each pair of corresponding points conveys its colour impression to the mental picture, the other being suppressed, but that in each eye the dominant and suppressed points are so closely intermingled that a mental picture of very fine grain is formed. Thus both colours appear to be seen simultaneously in the same place but yet not to be properly mixed. The half-faded disk in Experiment 6 represents a binocular mixture of black and white of this kind.

Experiment 12.—The experiment of Hecht (1928) stands in a different category. The yellow which is seen has none of the peculiar shifting appearance of the other allegedly binocular mixtures, but on the contrary is quite stable so that the experiment seems at first sight to be entirely convincing.

Part 2 of Experiment 12 shows, however, that this yellow is not due to binocular mixture, and Part 3 shows that the yellow colour is actually caused by the brightness of the lamp affecting the hue and saturation of what is seen by the right eye through the green filter. This apparently yellow patch suppresses the corresponding hue area on the left retina.

If Hecht's experiment is repeated, omitting the lamp and using only a plain white surface, the stability is lost, there is much rivalry, and any apparently binocular mixture has the same peculiar characteristics as those obtained by the other methods.*

On the whole, then, although the picture is far from clear, the results of binocular colour-mixture experiments appear to favour the suppression theory.

Depth Perception with Diplopia.—Tschermak and Hoefer (1903) and Wright (1951) have given evidence that some sense of depth is conferred by the disparity clue even when this is so great that diplopia occurs. Loewenstein (1952) has made the important observation that a depth effect is present even in Fig. 4(a). These results, which are impossible to explain by the fusion theory, do not oppose the suppression theory.

Suppression when Identical Portions of the Image fall on Corresponding Points.—The problem of whether suppression occurs when there is no disparity and identical stimuli fall on corresponding points is quite separate from those we have considered so far.

In a brilliant paper, du Tour (1760) described a series of simple experiments to show that when dissimilar stimuli fall on corresponding points only one of them is perceived. He then wrote:

Si les faits que je viens de rapporter concourent à établir que de deux objets qui se peignent dans les yeux il n’y en a qu’un seul qui affecte l’âme quand leurs images tombent, ou au points des retines où les axes optiques aboutissent, ou sur des points correspondants entre’eux, à plus forte raison serons nous fondés à admettre qu’un même objet ne peut produire en pareil cas qu’une seule impression efficace sur l’âme, quoiqu’il se peigne en même temps dans l’un et l’autre œil.

Thus he argued that since one of two dissimilar images on corresponding points always suppresses the other, so also must one of two similar images do likewise. This is evidence but it is not proof.

* No attempt is made here to explain the peculiar and important result of Hurvitch and Jameson (1951), who claim to have produced white from a binocular mixture of red and green.
The Logarithmic Argument.—Let us now suppose that there was a confluence of the visual pathways, and that the fusion took the form of a simple addition of the frequency of the action potentials, as would occur if fibres carrying impulses originating at corresponding points converged upon a single destination. It is instructive to calculate on this basis what would be the expected increase in brightness of an object viewed with one eye or with two. Experiments have shown that the frequency of the discharge is proportional to the logarithm of the physical intensity of the light stimulus. Also it is found that if a filter of Neutral Density 4 is placed in front of the eye under normal daylight conditions, then vision is possible through it without dark adaptation, i.e., this gives very roughly threshold intensity. The filter allows 1/10⁴ of the light to pass through, so that its removal increases the light intensity by 10⁴ times, and this results in a certain rate of discharge in the optic nerve. It follows that to double this rate of discharge it is necessary to double the logarithm of the light intensity, i.e., to increase it by a further factor of 10⁴. To do this would require an intensity of illumination equal to ten thousand times normal daylight. Now, opening or closing one eye while the other remains open causes scarcely any change in brightness of the object viewed, so that any simple fusion of the kind supposed is definitely excluded.

The Argument from Dissimilar Stimuli.—If it be taken as established for the case of disparity of the retinal images that one of each pair is always suppressed when dissimilar images fall on corresponding points, then separate evidence is required to show that suppression does not occur when similar stimuli fall on corresponding points. It seems that there is no good evidence to indicate this absence of suppression, and from the principle of economy of hypothesis, we should assume, at any rate provisionally, that suppression occurs in both cases.

Statement of the Suppression Theory of Binocular Vision

The correspondence of the retinal elements is completely rigid and unchanging.

One of a pair of corresponding points always suppresses the other.

Where there is a contour, the suppressing power of retinal elements on each side of it is enhanced.

Where there is disparity of contour, then in the one eye retinal elements on both sides of this contour will suppress corresponding points in the other eye.

If the extent of the suppression is smaller than the disparity between the contours, then diplopia occurs, but depth perception is possible.

If the extent of the suppression is greater than the disparity between the contours, one contour is suppressed and single vision occurs with depth perception.
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The contour of one part of the image may be dominant in one eye, and that of another part may be dominant in the other eye.

Summary

The theory is advanced that of a pair of corresponding points, one always suppresses the other.

Evidence to support this view is obtained by combining various line diagrams in a stereoscope and noting which portions are suppressed.

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REFERENCES
