AFTER-IMAGERY IN DEFECTIVE FIELDS OF VISION*  
BY  
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In a study of visual after-images of patients with homonymous hemianopia one would anticipate an after-image only in that part of the field which is perceived by the patient during fixation. Fuchs (1920, 1921), however, found that such patients saw more in the after-image than in the stimulus field or the perceived field of vision. Thus Fuchs noted that a figure only partly seen on fixation (the remainder of the figure was not seen because it was situated in the blind part of the field) was perceived by the same patient in its entirety in the after-image. This is known as the phenomenon of completion.† Using simple figures, such as circles and squares, Fuchs postulated that completion depended on the “inner structural requirements of the stimulus figures.” On the other hand, Bender and Teuber (1946), who also studied completion effects in impaired fields of vision, and used complex figures such as an American flag in complementary colours, believed that these effects need not necessarily be explained only by qualities of the stimulus figure. They observed that the after-image may represent only partial tendencies toward completion. Thus additional areas seen in the after-image or the “completed areas” did not always produce a smoothing of contours or the completion of a total figure. Sometimes there occurred in the after-image irregular additions to that which was perceived in the stimulus field.

The present investigation was undertaken to study the nature of after-image alterations in a patient with irregular but homonymous defects in the fields of vision following lesions in both occipital lobes. The test patterns used were simple geometric figures.

Case Report

J. G., a forty-year-old salesman, was admitted to the Mount Sinai Hospital in the latter part of 1946 because of occipital headaches, generalized weakness, and "bizarre" visual disturbances. There was a long-standing history of hypertension and arteriosclerotic cardiovascular disease. His average blood pressure during the illness was 200/120 mm. Hg. A bilateral sympathectomy for relief of hypertension had been performed in 1945. During the course of his long illness he had symptoms and signs of embolization to the lungs, kidneys, popliteal artery, and brain.

The cerebral infarcts which first occurred in 1942 were clinically localized to the occipital lobes. The visual symptoms consisted of episodes of blurring of vision to the left of his fixation point, spells of momentary blindness, teleopsia, micropsia, monocular diplopia, and dysmorphopsia. The perimetric and tangent screen examinations of the visual fields showed homonymous scotomas in the left upper quadrants and macular regions. There was also a relative scotoma in a small region of the right field of vision as indicated in Fig. 1. In 1946, and on admission to the Bellevue Psychiatric Hospital in 1948, a marked dissociated nystagmus was noted whenever he tried to view an object in his left field of vision. In the spring of 1948, the patient became worse, and he died in cardiac failure. Autopsy examination was limited to the brain. This revealed areas of infarction on the under surface of both occipital lobes. The ischaemic softening was greatest on the right side and extended forward but not into the temporal lobe. It included Brodmann's area 18, the inferior calcarine region of area 17, and the tip of the occipital pole. The lesion on the left was limited to a small region in Brodmann's area 18.

Method of Testing Visual After-Imagery

The figures (stimulus fields) used to elicit visual after-images consisted of various sized red and green coloured squares presented to the patient on a white background. Six different patterns were presented (series 1 to 6, as illustrated in Figs. 2 to 7). Binocular fixation was maintained on a small cross in the centre of the stimulus field. After sixty seconds' fixation the stimulus field was manually removed and the patient continued to fixate on a small cross on the white background which now served as the post-exposure or "after-field." Immediately, or a few seconds thereafter, the patient reported that he saw an after-image which was always a negative after-image. Conditions of illumination were varied. Usually the patient was seated at a desk and the stimulus and back-
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Fig. 1.—Visual fields (a) perimetric and (b) tangent screen. Illumination daylight, size of target 5 mm., distance 33 cm. Solid black indicates region in which perception of movement is absent. Vertical lines indicate area in which movement is perceived but there is marked blurring and fluctuation in the appearance of the target. Stippling represents area in which target is less blurred. The small circles within the right field indicate region in which vision was blurred or grey. The dashes represent the borders of the field of vision for colour red.

ground were exposed to ordinary desk lamp illumination. When the patient was confined to bed, only daylight illumination was employed. There was no appreciable difference between the results obtained under either type of illumination. The patient's eyes were approximately 30 cm. from the fixation point, and no more than seven or eight tests were made at any one session.

Results

Stimulus Field.—On fixing at the centre of the stimulus field the contour of the pattern actually seen by the patient corresponded to his field as plotted on the tangent screen (Fig. 1b). Under such conditions the area to the left of the fixation point was generally not reported. The line of division in the vertical meridian was irregular. It was somewhat S-shaped, as noted on the perimetric and tangent screen recordings. The lower left quadrant of the stimulus pattern was perceived only when large patterns were exposed, but colour was not well seen in this quadrant. To the right of the fixation point there was also an area of defective vision. This area varied in size and shape, and was reported by the patient as appearing "grey with white spots." (Figs. 1 to 7.) In the right superior quadrant the patient complained of blurring and "transparency" (Figs. 2 to 7). In this part of the field the true colour was perceived, although it varied in intensity.
Fig. 2.—The basic pattern in series 1. Stimulus field: a 50 mm. square, with X indicating fixation point in centre of figure. Perceived field: indicated by unshaded part of square. Cross hatching part of the field not perceived on fixation. White dots on grey background is zone which appeared blurred or grey. After-image figures in legends as above.

Fig. 3.—The basic pattern in series 2. Stimulus field: a 50 mm. green coloured square superimposed as illustrated on a 100 mm. red coloured square. Thus the green square was surrounded by a red border 25 mm. wide. Legends same as in Fig. 2.
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After-Image.—On almost every test the figure seen in the after-image appeared to be greater in area than that noted during fixation of the stimulus field (phenomenon of completion). However, the areas in which “completion” occurred showed varying degrees of instability. In the completed regions there was fluctuation in intensity with waxing and waning of colours, while the colour and brightness of the rest of the after-image remained relatively constant. Frequently the patient reported that this part of the after-image appeared dim. In addition, a “grey shadow,” insular in shape, appeared to the right of the fixation point completely obliterating the colour in this region of the after-image. The shape of the grey shadow, which corresponded to the relative scotoma elicited to the right of the fixation point on visual field tests, always had a clearly defined stable contour in contrast to the hazy shape of the faded-out border areas of the entire after-image. The visual after-image varied with the pattern used in the stimulus fields. This is illustrated on analysis of the following series.

Series 1.—In this group of tests the stimulus field consisted of single squares varying in size. A figure of either 50, 75, or 100 mm. square was presented in successive tests so as to determine whether the size of the stimulus field produced significant differences in the degree of completion of the figure in the after-image. The results showed that approximately the same amount of proportional completion was observed for each of the squares tested. Frequently almost the entire square was perceived in the after-image (Fig. 2). However, the left border of the figure at times appeared to be hazy and faded quickly. The right border was always clear. The extent of the area which appeared to be hazy in the after-image, which was always on the left side, was not fixed. It varied with the size of the stimulus presented. The larger the stimulus figure the greater was the absolute extensity of completion in the after-image.

Series 2.—In this group, 50, 75, and 100 mm. squares were again used in the stimulus field, but this time they were presented in various superimposed patterns. A smaller square (coloured green) was placed in the centre of a larger square (coloured red). Thus the stimulus fields consisted of a 50 mm. green square placed in the centre of either a 75 or a 100 mm. red square, or a 75 mm. green square was placed in the centre of a 100 mm. red square. The results in this group showed that the inner or smaller square was seen in the after-image always in its entirety. It was complete and showed stability, there being no parts missing and no fluctuation of the figure. In contrast to the strength and stability of the central square, the visible borders of the larger square tended to be slightly diminished in the after-image. At times the patient reported that he saw only one large square. There were no defects in the central regions of the after-image or in that which corresponded to the smaller square in the stimulus field. Characteristically the large complete square and the small complete square alternated in successive phases of the after-image.*

Series 3.—In this group the stimulus field consisted of four small squares arranged in a pattern to form a large square. They were spaced 5 mm. apart, subtending an area equal to a 50 mm. square; four 35 mm. squares spaced 5 mm. apart, subtending an area equal to a 75 mm. square; and four 45 mm. squares spaced 10 mm. apart, subtending an area equal to a 100 mm. square. The basic pattern is illustrated in Fig. 4.

In this situation the completion effect in the after-image appeared independently in each of the small squares. The results were comparable to those obtained with presentation of only one square at a time in each of the quadrants. Under these conditions there was never an after-image in the left superior quadrant of the field. In the remaining three quadrants the patient saw images of the squares, parts of which he could not see in the stimulus field (Fig. 4). At different times he reported that he saw three or two squares. He never saw the composite of four squares on a background in the after-image. The squares on the right side, especially the one in the right lower quadrant, were always seen in the after-image.

The after-images of the four squares also varied in regard to latency, intensity, and duration. In the right inferior quadrant the duration and stability of the after-image was more than in any other part of the field; the squares in the right superior and left inferior quadrants appeared somewhat later, were less vivid, and did not last as long as the one in the right lower quadrant.

Series 4.—In this group the stimulus field consisted of four small squares on a large square of a different colour, usually green on red. The basic pattern is illustrated in Fig. 5. Four 22·5 mm. squares were placed in the centre of either 75 or 100 mm. squares of a different colour, or four 35 mm. squares were

* Although nominally the entire stimulus pattern can be regarded as the figure, and the white field on which the pattern is placed as the background, figure-ground differentiation can also be made within the stimulus pattern itself when squares of different colours are presented symmetrically around the fixation point. One cannot arbitrarily assert that either the smaller or the larger square is the figure. The alternation of the perception of the squares in the after-image suggest a parallel to Rubin's reversible figures. There may be rivalry between the differently coloured squares, each alternating at being the figure, while the other is the ground, and consequently dominant in the after-image for a short period.
Fig. 4.—The basic pattern in series §3. Four 22.5 mm. green squares spaced 5 mm. apart so that the total area of figure is equal to a 50 mm. square. Area in right upper quadrant shaded with X indicates region in which colour of after-image appeared dim. Rest of legends as in Fig. 2.

Fig. 5.—The basic pattern in series 4. Four 22.5 mm. green squares arranged within a 50 mm. square area and superimposed on a 100 mm. red square. Legends same as above.
superimposed on a 100 mm. square of a different colour. With these test patterns there seemed to be a decrease in the extent of the total area occupied by the after-image. Only a small part of the perceived field (that in the right lower quadrant) appeared in the after-image. Nevertheless, that part of the stimulus figure which appeared in the after-image tended toward completion. For instance, the patient reported that he saw an entire square in the after-image whereas in the stimulus field he saw only part of the square. At times the one small square he saw in the right lower quadrant of the stimulus field appeared in the after-image as the central figure, with the large continuous square serving as the background. Here it seemed as if the small square perceived in the right lower quadrant of the stimulus field were apparently "displaced" toward the centre when seen in the after-image. On other occasions this square was "displaced" to a position just downward and to the right of the fixation point in the after-image.

Series 5.—In a variation of the last series, the stimulus field in this group consisted of smaller coloured squares superimposed at the corners of the larger square of a different colour, usually green on red. The basic pattern is illustrated in Fig. 6. Under these conditions there was a much greater tendency to see a uniformly coloured single large square in the after-image. After a variable latency the patient reported that he saw one or more of the small squares. The small squares, however, varied in latency of appearance and intensity of colour.

There were also several instances of apparent "displacement" in this series. The small squares in the right side corners were displaced diagonally toward the centre (Fig. 6). In one instance, only the right lower square was seen, and it was "displaced" horizontally toward the mid-line.

Series 6.—In this group the stimulus field consisted of a single coloured square superimposed on a larger field of four single squares of a different colour, usually red on green. The basic pattern is illustrated in Fig. 7. A 50 mm. square was superimposed on either four 35 mm. or on four 45 mm. squares; a 75 mm. square was superimposed on four 45 mm. squares. In the after-image the patient saw the entire stimulus pattern on two occasions. However, parts of the two outer squares on his left were indistinct or faded quickly. There were also further instances of displacement, but this time in a centrifugal direction. It can be seen in Fig. 7 that the discontinuous squares were displaced peripherally and were seen as almost complete squares.

Discussion

Our data show that the visual after-images in a patient with defective fields of vision vary with conditions of testing. In most instances the after-image shows completion. There is an increase in the extent of the figure over that perceived in the stimulus field.

These studies show that completion effects depend to some extent on the stimulus figure. Size and configuration of the presented pattern are some of the factors which determine completion. Increase in the size of a given stimulus pattern (such as a square) can produce a greater extent of completion (series 1). On changing the configuration within the stimulus figure (square) but keeping the contour and area constant (such as dividing the square as illustrated in Fig. 2 into four quarters as illustrated in Fig. 4) the degree of completion is decreased.

In comparing results in series 1 and 2 with series 3, it can be seen that when the stimulus figure is simple and continuous in contour, such as a single square (Fig. 2 in series 1, Fig. 3 in series 2) there is a greater extent of completion than when the stimulus figure is discontinuous, such as a composite of four small squares (Fig. 4 of this series).

Explanations for completion effects in visual after-imagery and in tachistoscopic studies have been offered by the Gestalt school. They postulate that the qualities of the figure in the stimulus field might be partly responsible for the phenomenon of completion. Some of the qualities they consider as primary in perception are "goodness," "continuation," and "closure" of the figure.* According to Koffka (1935) (after Wertheimer) "psychological organization will always be as "good" as the prevailing conditions will allow."

It is well known that in normal subjects the figure in the stimulus field may undergo changes in the after-image. Thus the after-image of a square might gradually lose its sharp corners and become more and more circular. Rothschild (1923) found that the occurrence of an after-image itself depended on whether it made a "good" shape or not; that if the contours in the stimulus figures were "good," or formed a simple shape, such as a square or a circle, they produced satisfactory after-images, even

* By "goodness" of the figure the Gestalt psychologist means the ease with which a figure can be perceived under certain conditions. For instance, a circle at high speeds of exposure can be recognized more readily than a figure of irregular outline. The concept of "goodness" includes such figural properties as regularity, symmetry, and simplicity, as in a square, circle, and similar geometric figures. By "continuation" the Gestaltists imply that the perceiving subject adds features to a repetitive pattern. Thus if a wavy line is presented and the last wave is incomplete, the subject would report a complete wave. By "closure" is meant the tendency of a subject to report a simple pattern (such as a circle) as complete even though there was a small gap in the stimulus figure. For greater details see Koffka (1935). In addition they consider the factors of internal organization of the figure and the relation between figure and background.
FIG. 6.—The basic pattern in series 5. Small green-coloured squares 22.5 mm. placed in each of corners of a 100 mm. red coloured square. Legends as above.

FIG. 7.—The basic pattern in series 6. One 50 mm. green square superimposed on four 45 mm. red squares. Total area of stimulus field 100 mm. square.
improving on the originals (stimulus figures) inasmuch as all slight irregularities would disappear. If, on the other hand, the lines of the stimulus figure did not form a simple shape, such as an irregularly shaped square or circle, the after-image would either be a “better” shape or several of the lines would not appear in the after-image. Frank (1923), Shibata (1936), and Schottlaender (1936) have reported changes in the after-image as a function of the figural qualities of the after-field (the stimuli applied to the retina during the experience of the after-image).

According to Fuchs (1920, 1921) completion can also occur when there is sufficient perception on fixation to determine the “law” of the entire figure. In Gestalt terms a figure can be said to have a law when it is organized in a highly stable fashion, that is, if it is characterized by the properties of “goodness.” It is then only necessary for the observer to perceive enough of the figure to allow the “internal organizing forces” to become established in order for completion to occur. In our case the patient perceived squares or the greater part of a square. The law of the figure was a square.

From other findings in our case it would seem that the completion effects noted in the after-images might illustrate such a Gestalt principle as “closure.” The filling-in in the after-image of areas of relative scotoma and the completion of gaps in the contour of the figure perceived in the stimulus field might serve as an example of closure. Unfortunately our studies were not very exhaustive. The patient’s continued poor health did not permit us to make all the tests which we would have liked. Hence we do not have sufficient data to support the theory that figural qualities alone are responsible for the phenomenon of completion in visual after-images.

Our results also revealed that the after-image of a figure may be considerably enhanced when there is a background or surrounding field of stimulation. This was shown in series 2 (Fig. 3), in which a smaller enclosed figure was more completely seen and possessed more stability than when shown alone. This phenomenon has been previously noted by Koffka, and also appears to be related to the findings summarized by Bartley (1941), in which a surrounding border influenced the differential brightness threshold of central areas. Apparently the presence of a surrounding field has an effect on the gradient of function of the enclosed figures.

Besides completion, the after-images in our case showed variation in latency, intensity, and duration. On testing each of the four quadrants of the perceived field it was found that the after-image of a figure studied in the left lower or in the right upper quadrant appeared after a longer latency, was lighter in colour, and faded more quickly than the after-image of figures which were exposed in the left upper quadrant. It is well known that latency, intensity, and duration of the after-image in normal as well as pathological subjects may vary from one examination to another. It is also known that these variables are systematically altered in patients with cerebral lesions (Brückner, 1917; Vujic and Levi, 1939; Ruesch, 1944). However, the changes noted in our case were consistently greatest in the affected quadrants. In the patient’s normal right lower quadrant of the perceived field the variations in latency, intensity, and duration were minimal. Since these changes always occurred in a certain part of the after-image field they might assume clinical significance. On using this method in other cases it was found that decrease in intensity and duration and increase in latency occurred consistently in homonymous parts of the after-image field of each eye. In fact, in some cases the method of after-imagery demonstrated a defect in the homonymous fields which routine perimetry failed to disclose. On the other hand, due to the occurrence of completion, visual after-imagery cannot be substituted for the perimetric method. Williamson (1945) advocated visual after-imagery as a quick method for determination of defects in fields of vision, but he did not take into account that after-imagery often reveals a lesser defect than does campimetry.

In conclusion it is evident that a study of the fields of vision by the method of visual after-imagery yields information which other methods such as perimetry and tangent screen examinations fail to reveal. Although the changes elicited on visual after-imagery are frequently variable, they are still significant inasmuch as they occur consistently in a given part of the field. They can be found within, and adjacent to, parts of the field of vision which seem to be defective. Moreover, the changes conform to a pattern and occur in homonymous parts of the visual after-image of each eye. The pattern of the after-image field is determined by the fixed relation between the apparently defective and normal parts of the fields of vision.

Summary

1. Completion effects (an increase in the extent of the figure in the after-image over that in the perceived field) in the visual after-image of a patient with homonymous scotomas were studied by varying the geometric pattern within the stimulus field.

2. The size and configuration of the stimulus figure, as well as the presence of a surrounding field of stimulation, are some of the many factors which
alter the visual after-image and lead to completion.

3. Consistent changes in latency, intensity, and duration can be shown in homonymous parts of the after-image field, whereas the corresponding regions in the perceived field show no defects.

4. Visual after-imagery can be used as another method of demonstrating defects in field of vision. On the other hand, due to completion effect, visual after-imagery cannot be substituted for the perimetric or any other method of testing vision.

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