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THE MEMORY EFFECT OF VISUAL PERCEPTION OF THREE-DIMENSIONAL FORM

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The kinetic depth effect that has been discussed in a preceding paper (2) enables monocular *Ss* to perceive three-dimensional form as directly as do persons with serviceable binocular vision by means of retinal disparity. Yet this effect alone does not, of course, solve the entire problem of the perception of solid form. Three-dimensional form is seen monocularly also when the observer does not move in relation to the object and it is also perceived in photographs and drawings. It has been mentioned in the preceding paper that an empiristic explanation of these cases of three-dimensional form perception becomes more feasible through the demonstration of the kinetic depth effect. This is so because no empiristic explanation can be termed successful until it is made clear how the original process or experience is brought about under whose influence current experience is supposed to occur. Prior to the demonstration of the kinetic depth effect (KDE) no process was known which could account in a satisfactory way for the "original" perception of three-dimensional form in monocular *Ss*.

Two different approaches have been made to explain the perception of three-dimensional form that occurs in the absence of retinal disparity or of other specific cues for visual depth. It has been proposed that three-dimensional forms are seen under these circumstances because the corresponding retinal patterns have the power to evoke them directly. Gibson (1), who holds such a view, believes that such retinal patterns have geometric characteristics which are specific stimuli for depth just as there are specific stimuli for color, pitch, etc. Many Gestalt psychologists believe that visual processes are spontaneously organized so that certain patterns of stimulation lead to three-dimensional forms and others to plane forms in perception and they have tried to formulate the principles which underlie such organization. When three-dimensional objects are seen as three-dimensional forms, it is due to the fact that their retinal projections have properties which favor organization as three-dimensional forms. The other approach is, of course, the empiristic one. It is believed that previous experiences can cause a present perception in three dimensions.

For a number of reasons, one of which—the nature of the KDE itself—will be discussed below, we came to believe that an influence of past experience plays an important role in the perception of three-dimensional form and set out to demonstrate such an effect in a stringent way. Such a demonstration requires that a retinal pattern, which at the outset is seen as a plane figure, gives rise under identical external conditions to the perception of a three-dimensional form after an intervening exposure of the same pattern given under conditions which cause it to be seen as three-dimensional.

METHOD

There are several ways in which a pattern can be made to appear as a three-dimensional form in the intervening exposure. We found it most appropriate to use the KDE for this purpose, and

experiments were done with a shadow technique (2). A three-dimensional wire figure was placed behind the translucent screen which was so chosen that its shadow visible on the other side of the screen looked two-dimensional to all *Ss* in a stationary exposure. In the intervening exposure, the wire figure was turned back and forth so that a deforming shadow was cast which *S* eventually perceived as a three-dimensional form due to the operation of the KDE. This was followed sooner or later by the test exposure in which the same stationary shadow was presented which had been shown in the first exposure. The critical question of the experiment was whether or not it would now appear three-dimensional.

The same wire figures were employed as in the experiments of the preceding paper (2). They were the "helix," the "parallelogram," and the "110° corner." Three experimental series will be reported and in each all three figures were presented. However, the purpose of experimenting with the 110° corner was different from the purpose of experimentation with the other two figures. Merely for technical reasons were all three figures presented in the same series. The results for the 110° corner will therefore be discussed separately at the end of this article. We begin with a description of the three series. Since each of the series, insofar as the helix and the parallelogram were concerned, was designed to answer a different question, the results of the different series will be separately presented and discussed.

The experimental series were composed of moving exposures and of stationary presentations of the various figures shown individually. In the moving exposure the wire figure behind the screen rotated back and forth through an angle of 42° at the rate of one cycle in 1.5 sec. The shadow was shown for 10 sec. by turning the lamp in whose light the shadow was visible on and off, and then *S* was asked for a report on what he had seen. The 10-sec. exposure was repeated until the report clearly indicated that *S* had seen the correct three-dimensional form. If this did not happen within 12 such exposures, the moving presentation was listed as having failed.

The shadow for the stationary presentation was cast by the wire figure in a position within the range of the rotation of 42°. Figures 2, 3A, and 4 of the previous article (2) show the shadows employed in the stationary presentations. All stationary presentations employed the same shadow of each wire figure and lasted for 5 sec. Our *Ss* were undergraduates of Swarthmore College.

Series I.—There was first a stationary exposure of the 110° corner. Then, moving exposures of the helix, the 110° corner, and the parallelogram were given. Stationary test exposures of the three figures in the same order followed. Thus, the moving exposure and the test exposure of a given figure occurred a few minutes apart. For the helix, the moving exposure of the 110° corner and of the parallelogram intervened, and, in the case of the parallelogram, the stationary exposures of the helix and of the 110° corner came between the moving and the test exposure of that figure. This series was presented to 33 *Ss*.

Since no stationary exposure of the helix and the parallelogram was made in this series prior to the moving exposure, stationary presentations of these figures were given to a control group of 16 *Ss* to find out what percentage of *Ss* would see the figures two-dimensional at the outset.

Series II.—Here two groups of 20 *Ss* were employed. Only the 110° corner and *one* of the other two figures were presented in moving exposure. The remaining figure served as a control and was given only in the final stationary exposure together with the two experimental figures. Thus, for an *S* of the helix group the sequence of presentation was the following: First came a stationary exposure of the helix followed by one of the 110° corner. Thereupon, the moving presentations of the helix and of the 110° corner were made in that order. These were followed by stationary exposures of the helix, of the 110° corner, and finally of the parallelogram which had not been seen by these *Ss* before. For *Ss* of the other group, the parallelogram was given in place of the helix and vice versa.

Series III.—This series differed from Series I only in two points. The sequence in which the figures were presented both in the moving and in the stationary test exposure was parallelogram, helix, and 110° corner. Also, a large time interval was introduced between the moving and the test exposures. For 12 *Ss* this interval was 24 hr. and for 11 *Ss* seven days.

Results for "Helix" and "Parallelogram"

The purpose of Series I was simply to demonstrate that the perception of a three-dimensional form in the moving exposure would tend to make the figure appear three-dimensional in the stationary test exposure also. Evidence that prior to a moving exposure our two figures appear two-dimensional in stationary presentation comes here from a control group of 16 *Ss*. Both figures were seen plane by all of them.

The results for the moving and for the test exposure are simple in the case of the parallelogram. All 33 *Ss* saw this figure three-dimensional in the moving exposure and all of them reported the same three-dimensional form in the stationary test exposure. In the case of the helix, 31 of the 33 *Ss* reported this figure as three-dimensional in the moving presentation after various exposure times; the remaining 2 saw it as a plane deforming figure and saw it two-dimensional in the test exposure also. Of the critical 31 *Ss* who had seen the helix three-dimensional in the moving presentation a majority of 26 reported seeing the three-dimensional form when the stationary shadow of the figure was presented in the test exposure; the remaining 5 *Ss* saw a plane figure.

These results demonstrate a strong influence of an earlier experience in the perception of three-dimensional form. What is the nature of this influence? Does it consist in a tendency to see further figures three-dimensional after some have been perceived in this fashion under the same circumstances, or is it an influence of an earlier perception of a particular figure on the perceptual process which takes place when this particular figure is given again? Series II was designed to answer this question. It will be remembered that only one of the two figures was presented to a given *S* in moving exposure, but both figures were presented in the test exposure. If we are dealing with a general tendency, both figures should be seen three-dimensional in the test exposure by a majority of the *Ss*. If the influence is in the nature of an individual figure causing a later exposure of that figure to be seen in the same three-dimensional way, only the figure previously given in moving exposure should appear three-dimensional.

In this series a stationary control exposure of the figure for which an aftereffect was to be established was given to the experimental *Ss* prior to the moving presentations. All 40 *Ss* saw the figure that was presented to them as being two-dimensional and this confirmed the results of 16 control *Ss* of Series I.

In the moving exposure, 18 out of 20 *Ss* saw the helix three-dimensional and all *Ss* perceived the parallelogram in this fashion. In the stationary test presentation, 13 out of the 18 *Ss* who had been given a moving exposure of the helix and had then seen a three-dimensional form saw this figure again three-dimensional, and 5 reported a plane figure. The parallelogram was seen three-dimensional by 17 of the 20 "parallelogram *Ss*." These data agree well with those obtained in Series I and show a strong influence of the perception of three-dimensional form in the moving presentation on the reports in the test exposure. The new information to be gained from the present series comes from the test exposures of the figures which had *not* been previously presented to the respective *S*. Of the 20 *Ss* who had been given the parallelogram in moving exposure and had seen it three-dimensionally, only one perceived the helix in three dimensions. The results are somewhat different for the parallelogram in this situation. As many as 7 of the 20 *Ss* to whom it had not been presented in moving exposure reported seeing it in three dimensions (19 of them had seen at least the 110° corner three-dimensional).

For the helix, these results are quite unequivocal. Whereas 13 out of 18 *Ss* who had seen this figure three-dimensional before saw it so in the text exposure, this was the case with only 1 out of the 20 *Ss* who had seen only the other figures in this fashion.

The influence which causes the perception of three-dimensional form in the stationary test exposure appears to come from a previous three-dimensional perception of the *same* figure only. For the parallelogram we have to compare the result 17 out of 20 *Ss* who had seen the same figure three-dimensional with 7 out of 19 *Ss* who had seen only either one or two other figures in this fashion. Although there is for this figure an influence of a general kind, the specific influence which comes from a previous three-dimensional perception of the same figure is much stronger. It should be mentioned that the shadow of the parallelogram is more easily seen in three dimensions than that of the helix. Often a mere suggestion like "could this be a tetrahedron" suffices to make this figure appear three-dimensional. When the results for the helix and the parallelogram are taken together, the difference between the cases due to a general effect (8 out of 40) and those cases where the same figure had been seen three-dimensional before (30 out of 38) is reliable at better than the .01 level of confidence. It seems safe to conclude that our aftereffect consists in an influence of the perception of a figure upon a subsequent perceptual process which takes place when the same figure is given again, and that, in the case of some figures, previous exposures of different figures may exert a similar influence as if by suggestion. (Further evidence on this point comes from the experiments with the 110° corner reported below.)

Some readers may find difficulty with this formulation. How do we know, they may ask, that we have here really an effect on perception, that *Ss* actually *saw* a three-dimensional form? It could be that *Ss* reported a three-dimensional form because they had previously seen the same pattern on the screen as three-dimensional and knew that the pattern represented such a form. The evidence on this point is clear and simple. When directly after the test exposure *Ss* were allowed to inspect the stationary shadow for a longer period, a large percentage of them reported Necker cube-like reversals of the figures that they had described. Everybody who has seen a drawing of a three-dimensional figure reverse will agree that only an actually perceived three-dimensional form will exhibit these changes. Where these reversals occur, coming on unexpectedly and initially appearing to be objective, three-dimensional forms are seen with all concreteness. Many *Ss* of Series II who had reported seeing three-dimensional forms on the test presentation were given prolonged exposures of the stationary figures. For the helix, 13 out of 14, and for the parallelogram, 20 out of 24 *Ss* reported reversals spontaneously.

In Series I and II, the time interval between the perception of a figure as a three-dimensional form and the test presentation amounted to a few minutes. In Series III this time interval was much longer. Twelve *Ss* were tested after 24 hr. and 11 after seven days. All *Ss* perceived a three-dimensional form in the moving exposure of both figures. In the 24-hr. group, all *Ss* saw the parallelogram three-dimensionally in the test exposure and 11 out of 12 did so in case of the helix. In the seven-day group these numbers are 10 out of 11 for both figures.

In this series the test for the parallelogram always preceded that of the helix, and this may have favored a three-dimensional appearance of the helix. We therefore report data from another similar experiment where, after a 24-hr. interval, the helix was the first figure tested. Of nine *Ss* who had seen the helix three-dimensional in the moving exposure, seven saw it three-dimensional in the test presentation.

It appears from these data that the aftereffect can be obtained virtually undiminished after longer time intervals, and that it should be termed a memory effect. Moreover, the results of Series II indicated that we were dealing largely with the effect of individual memory traces.

How does a memory trace produce its effect

on the perception in a test exposure? Does it merely give an indication that the pattern concerned must be perceived as three-dimensional or has a trace the capacity to determine a specific three-dimensional form for the new perception? So far, the answer to this question comes only from a consideration of the kinetic depth effect (KDE) which was described in the previous paper (2). The very nature of this process makes it necessary to ascribe to a memory trace the power to determine the organization of a visual form process. Stimulation for the KDE consists in a deforming retinal projection which is produced when a three-dimensional object changes its orientation to *S*. At any moment the retinal projection assumes a slightly different shape and every one of these momentary images can have a form such that it would produce a perception of a two-dimensional figure, if it were presented by itself, that is, not in the context of the deforming projection. However, within the context, that is, when it is given in continuous sequence with all the other momentary images which make up the deforming projection, it produces the perception of a three-dimensional object which changes its apparent orientation to *S*. The apparent momentary aspect of the perceived object corresponds to the particular retinal image which is given at that moment. This makes it clear that any one of the momentary retinal images gives rise to a perceived three-dimensional form only because it was preceded by a number of different images of the object. At the moment when it is given on the retina the preceding images are matters of the past. Pertinent stimulation is given in temporal sequence and the perceived form is its cumulative result. From the moment at which three-dimensional form is first perceived, a complex memory trace which represents this result of the preceding stimulation must be assumed to participate in the perceptual process. To be sure, this trace alone is not the correlate of perceptual experience; stimulation by one of the momentary retinal images is also necessary to bring about the three-dimensional percept. But it is obvious that the perceptual process to which a momentary image gives rise must attain its form in three-dimensional space due to such a trace.

If perceived three-dimensional form must be ascribed to the organizing power of a trace in the case of the KDE, it seems justifiable to assume that the effect of a trace in our test exposure is of the same nature. The motion of any one of our wire figures in kinetic presentation can be stopped and *S* will continue to see the stationary shadow as the three-dimensional form that he had seen during the moving presentation. There appears to be no reason to assume that at this point, a trace action of a different nature takes place. One should rather think that here, too, the trace causes perception of a specific three-dimensional form. It may be mentioned that such consideration of the nature of the KDE was one of the reasons why we expected to find a wide influence of past experience on form perception.

Results for "110° Corner"

We have shown that a memory effect on form perception is easily demonstrated and that it readily bridges large time intervals. We are inclined to believe that this effect plays a large role in ordinary perception of space and of solid form. We think that, at least in the adult, memory effects are responsible for the majority of instances of perception of solid form and of the spatial arrangement of the objects in the visual field.

If this is so, why did we demonstrate the effect only with two different figures? The answer is that suitable wire figures are hard to find because the shadows of most of them look three-dimensional from the outset. We believe that this is so because of the great wealth of previous experience with three-dimensional form. A pattern, like Fig. 1, that can be interpreted as representing three surfaces meeting to form a spatial corner, will always be seen in that fashion. This is true even in cases where such a

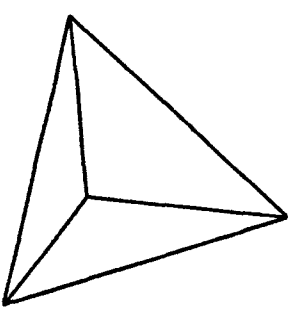

Fig. 1. Figure always seen as three-dimensional

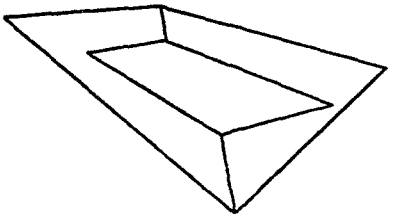

FIG. 2. Figure that makes no sense as a three-dimensional form

pattern is part of a large one as in Fig. 2. Although this figure as a whole makes no sense as a three-dimensional form to most *Ss*, three-dimensionality is seen at the two places where three lines meet to form a **Y**, most convincingly so at the lower one. Such a **Y**-shaped pattern is very frequently present in the projections of solid objects, as, for instance, in the projections of corners of boxes and of rooms, and there is much occasion to establish previous experience of three-dimensionality in connection with it. Wire figures which contain it are not suitable for our experiments where the given shadow pattern ought to appear two-dimensional in the control exposure.

Yet, there is nevertheless a way to make use of such a pattern for the demonstration of a memory effect, namely, if we are satisfied with establishing a modified three-dimensional form in the moving exposure. A **Y** pattern will look like the edges of a corner to many *Ss*, but that corner will frequently appear rectangular, presumably because in the great majority of previous encounters the **Y** pattern has been produced by a rectangular corner and has been seen as one. If, in the moving exposure, the **Y** pattern can be made to appear, say, as an obtuse corner, there is then the question of how it will look in the test exposure. If it is again seen as an obtuse corner, an aftereffect of previous experience has been established within our experiment.

Such an experiment was performed with the 110° corner. As mentioned above, this figure was presented in all three experimental series and in every one the control exposure was given to the experimental *Ss*. Thus, all *Ss* were given first a stationary control exposure, then a moving presentation, and finally a stationary test exposure of this figure. Fortunately, this particular **Y** pattern was seen as a two-dimensional figure in the control exposure by as many as 56 of the 96 *Ss* who participated in the three series, a number much higher than we had hoped for when the experiment had been planned; their results will be reported later. Of the remaining 40 *Ss*, 17 saw an obtuse corner in the control exposure and 23 saw a rectangular one. With regard to the question just raised, we are concerned with this latter group. In the case of 2 *Ss* of this group, the moving exposure failed to produce a perception of an obtuse corner, which reduces the number of *Ss* in this pertinent group to 21. Of these 21 *Ss* who did see a rectangular corner in the control exposure and an obtuse corner in the moving exposure, 8 reported a rectangular corner in the test presentation and 13 an obtuse corner. While the former did not display an aftereffect of perception in the moving exposure, the 13 *Ss* who saw an obtuse corner in the test presentation saw the shadow as one three-dimensional form at the outset and later, presumably as a memory effect of the moving exposure, as a different one. It means that a single experience can modify a form perception which itself may well be the outcome of previous experiences.

The total result of the experiment with the 110° corner is given in Table 1. It lists the results of all three

TABLE 1

NUMBER OF *Ss* GIVING VARIOUS RESPONSE SEQUENCES TO 110° CORNER

	A No Change			B Full Aftereffect			C Partial Aftereffect	D No Aftereffect		E Random Result	
Control	2D	Rect.	Obt.	2D	2D	Rect.	2D	2D	Rect.	Obt.	Obt.
Moving	2D	Rect.	Obt.	Rect.	Obt.	Obt.	Obt.	Obt.	Obt.	Obt.	Obt.
Test	2D	Rect.	Obt.	Rect.	Obt.	Obt.	Rect.	2D	Rect.	2D	Rect.
Series I	0	0	5	1	8	4	7	1	3	2	2
Series II	1	1	4	1	19	4	3	5	1	0	1
Series III	0	1	2	0	9	5	0	1	4	0	1
Total	1	2	11	2	36	13	10	7	8	2	4
Grand Total	14			51			10	15		6	

experimental series and is arranged in the following manner: Above the center line there are listed the 11 occurring combinations of *Ss*' reports in the three exposures. They play the role of headings for the 11 columns of data below and they are grouped under 5 capital letters in a manner which will be explained later on. The first horizontal row refers to the first stationary or control exposure; the second to the moving exposure; and the third row to the second stationary or test exposure. For instance, an *S* who sees the corner as a two-dimensional figure in the control exposure, as an obtuse corner in the moving exposure, and as a rectangular corner in the test exposure falls under the combination heading below the letter C (2D, Obt., Rect.), and the number of *Ss* who gave this particular sequence of reports in each series is given under this heading. The first three horizontal rows of numbers give the results for the three series separately and the fourth row the totals.

All three combination headings under A show no change from one exposure to another and the 14 *Ss* who gave these report sequences did not contribute in any way to the outcome of the experiment. This reduces the total number of *Ss* to be considered to 82.

The headings under B have two features in common: the reports for the moving exposure differ from those for the control exposures in the direction of a more adequate perception of the spatial form of the corner, and the reports for the moving and the test exposure are the same. Thus, these three headings represent three report sequences which denote a memory effect of the experience in the moving exposure on perception in the test exposure. However, to the 51 *Ss* who gave one of these report sequences should be added the 10 *Ss* under C who, although they did not give the same report in the test exposure that they gave in the moving exposure, nevertheless showed a change in the proper direction, if the control and the test reports are compared; they reported a plane figure in the former and a rectangular corner in the latter.

The two report sequences under D represent those cases that could have shown a memory effect of the perception in the moving exposure but did not; that is, the reports in the test exposure were the same as the reports in the control exposure. Under E two report sequences are listed which

make no sense, and the total of six Ss listed here gives an idea to what degree randomness figures in our results.

It should be pointed out that the data in the third horizontal row (Series III) were obtained with intervals of 24 hr. or seven days between the moving and the test exposures. The results for this group of 23 Ss do not differ significantly from those obtained after brief intervals (Series I and II).

To summarize: Of 82 Ss, 61 gave reports indicating a memory effect operating between perception in the moving and perception in the test exposure, 15 showed no such effect, and 6 gave results which denote independence of the perception in the test exposure of both preceding exposures. With three-quarters of the Ss yielding positive results, this experiment represents another demonstration of a memory effect on form perception.

The data given in Table 1 also throw light on an issue that has already been raised with regard to the two other wire figures, namely whether the aftereffect is caused by a previous three-dimensional perception of the *same* figure, or whether the figure is seen three-dimensional because of a general tendency arising in the experimental situation to see further figures three-dimensional. If the latter were true, one might expect that those Ss who see the corner three-dimensional in the test presentation as the result of an aftereffect will report a rectangular or an obtuse corner in about the same proportion as do Ss who see this figure three-dimensional at the outset. Among the 96 Ss, 40 saw the corner three-dimensional in the control exposure and of these 23 reported a rectangular and 17 an obtuse corner. On the other hand, a total of 48 Ss saw this figure three-dimensional in the test presentation as an aftereffect of the moving exposure; they are listed under the following three headings: 2D, Rect., Rect.; 2D, Obt., Obt.; and 2D, Obt. Rect. If the aftereffect consists in a general tendency to see the figure three-dimensional, one should expect these Ss to report a rectangular or an obtuse corner in about the same ratio as the previously mentioned 40 Ss, that is, in a proportion of about 23 to 17. This was not the case; only 12 Ss reported a rectangular corner and 36 an obtuse corner. The difference between 12 and 36 is reliably different from the difference between 23 and 17 at the .01 level of confidence.

If, on the other hand, the appearance of the corner in the test presentation largely depends on the perception of the corner in the moving exposure, we should expect to find a preponderance of Ss reporting an obtuse corner in the test, because 46 of the 48 Ss saw an obtuse corner in the moving exposure. This was indeed the case; 36 of the 46 Ss reported an obtuse corner again in the test presentation and the hypothesis that these two results are related is confirmed at the .01 level of confidence. In other words, these results can be ascribed, at least in part, to an influence of a specific perceptual experience upon a later perceptual process.

Summary

The shadows of three different three-dimensional wire figures were shown on a translucent screen. These figures were so chosen that their shadows appeared two-dimensional to the majority of Ss. By use of the kinetic depth effect, that is, by turning the wire figures back and forth, the shadows were then made to appear three-dimensional. After intervals which ranged from minutes to a week, the

stationary shadows were presented again in the same fashion in which they had been exposed originally and were then reported to appear three-dimensional by a large number of *Ss*. In order to make certain that these reports were based on three-dimensional percepts, rather than on inferences concerning the perceptual objects, a number of *Ss* were given prolonged test exposures and nearly all of them reported spontaneously reversals of the kind which are usually demonstrated with a Necker cube. Thus it was demonstrated that a previous perceptual experience can cause a later form perception to be three-dimensional. Evidence was presented that general set played only a minor role in the reported experiments and that the aftereffects obtained were to a large part due to the influence of the memory of individual figures.

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