Some evidence for the size-distortion explanations of illusions

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Eleven male Ss evaluated five forms of the concentric-squares illusion. The results suggest that this illusion is produced primarily by distortions in the size of the test figure rather than distortions in the locations of its contours. The method employed in obtaining these data can be used to provide information about the size-distortion components of other phenomena such as figural aftereffects, time and space errors, and apparent motion.

Explanations of geometric illusions may be divided into two sets, defined by the primary attribute along which the distortions are assumed to occur. The explanations proposed by Obonai (1933, 1954), Köhler & Wallach (1944), Köhler, (1965), Osgood & Heyer (1951), George (1962), Motokawa (1950, 1970), Deutsch (1964), and Ganz (1966) are based on the hypothesis that illusions involve distortions in the *locations* of the test (T) contours. Thus, the traces of the T contours shown in Fig. 1a are shifted towards the traces of the parallel inspection (I) contours. The T figure appears larger than the comparison (C) figure, but this is a consequence of the distortions in the locations of its contours. In contrast, the explanations proposed by Gregory (1963), Cleary (1966), Virsu (1968), Helson (1964), Restle & Merryman (1969), and Howard¹ are based on the hypothesis that illusions involve distortions in the *size* of the T figure. Although the locations of the T contours shown in Fig. 1a may be modified, this is a consequence of the distorted size of the T figure.

Despite the apparent differences between the location- and size-distortion hypotheses, there have been no studies which clearly distinguish between them, as most illusions could involve either location or size distortions. It is possible, however, to dissect systematically the concentric-squares configuration shown in Fig. 1a to produce the configuration shown in Fig. 1e, which may be used to test these hypotheses.

The location-distortion explanations include the assumption that distortions occur at right angles to the orientation of the I contour. Figure 1e contains only the vertical contours; thus, the location-distortion hypothesis states that the T contours should be shifted towards the I contours. Since there is no I contour parallel to the ends of the T contours, this hypothesis also states that there should be no change in the apparent lengths of the T contours.

The size-distortion explanations include the assumption that illusions involve interactions between figures. Figure 1e still consists of concentric squares, although they are represented by only their vertical contours. Thus, the size-distortion hypothesis states that the T figure would appear larger, which means both a change in the apparent location of the T contours and a change in their apparent lengths. The location- and size-distortion hypotheses may therefore be tested by determining whether or not the lengths of the T contours shown in Fig. 1e are distorted.

SUBJECTS

The Ss were 11 male undergraduates enrolled in a course in introductory psychology at Colgate University.

APPARATUS

The five stimulus configurations (Fig. 1) were drawn in black ink on white matte-surfaced cards. They were shown to the S through a circular opening, 15 cm in diam, in a circular display which was 1 m in diam. The S's chair was fixed to the display and

was provided with a headrest so that the S-to-stimulus distance was always 1 m. The display lights were controlled by a Hunter timer.

The response apparatus consisted of a continuous roll of white paper which appeared through a 9 x 5 cm window in a 21 x 25 cm piece of black Masonite. The luminance from either the stimulus cards during stimulus presentation or the response tape during response recording was always 1 mL.

DESIGN

The five stimulus configurations shown in Fig. 1 were presented both with the T and I figures on the left and right of the C figure. Thus, there were 10 combinations of figures and positions.

The Ss participated in two sessions. In the first session, each S judged two sets of cards. The 10 stimulus combinations were presented in a random order in the first set and in the reverse order in the second set. The two sets were preceded and followed by control trials on which only two lines with equal lengths were presented (Fig. 1f). The second session consisted of four sets of trials. The 10 stimulus combinations were presented in new random orders for the first and third sets and in their reverse orders for the second and fourth sets, respectively. Control trials were presented before the first and third sets and after the second and fourth sets.

PROCEDURE

The Ss were instructed to draw two lines on the response tape, which had the same relative lengths as the vertical contours of the T and C figures which were closest to each other. Each trial

Fig. 1. The stimulus configurations used in the experiment and their dimensions. I = inspection figure, T = test figure, C = comparison figure.

started with the lights in the room off. The E counted to three and started the timer which turned on the display lights for 3 sec. At the end of the presentation interval, the S turned immediately to his left and switched on the response light. After recording his judgments, he advanced the paper and turned the response light off. There were four practice trials before each session began, with stimulus combinations selected randomly from the set of 10. There was a 5-min rest period between the second and third sets in the second session. All viewing was monocular with the dominant eye.

RESULTS

The formula used to compute the amount of illusion on each trial was:

$$\% \text{ Illusion} = \frac{L_t - L_c}{L_t}$$

where L_t and L_c were the respective lengths of the T and C lines drawn by the S. The left or right control line was designated randomly as the T line before each session for each S, and the control-trial data was analyzed using the same formula.

Figure 2 displays the results of the experiment. As can be seen, all of the experimental configurations produced large distortions relative to the distortion produced by the control configuration. This was confirmed by a Treatment by Subjects analysis of variance (Winer, 1962) ($F = 11.13$, $df = 5,50$, $p < .001$) and by Duncan's new multiple range test (Winer, 1962), which indicates that all of the distortions produced by the illusion configurations are significantly different from the distortion produced by the control configuration at the .001 level. None of the other differences between means is significant at the .05 level.

DISCUSSION

The results of the experiment support the size-distortion hypothesis. The location-distortion explanations predict that there should be no change in the size of the T lines shown in Fig. 1e, whereas the size-distortion explanations predict that there should be considerable distortion. The results indicate that there is a 16.9% distortion for the vertical-lines configuration shown in Fig. 1e, compared with an 18.4% distortion for the concentric-squares configuration shown in Fig. 1a. Both scores are significantly greater than those for the control configuration and are not significantly different from each other. It seems reasonable to conclude that the concentric-squares illusion is produced primarily by size, and not location, distortion.

Fig. 2. Percentage of illusion produced by the six stimulus configurations.

Unfortunately, it is impossible to make specific predictions about the concentric-square illusion from most of the size-distortion explanations because the explanations are imprecise. Gregory (1963), for example, attributes size distortions to misapplied size constancy. Any situation in which there are perspective cues will lead to distortions in the size of the T figure. Since perspective is not well understood, the presence of an illusion must often be used to determine that the cues for perspective are present. Thus, it is difficult to predict that the frame provided by the I lines in Figs. 1d and 1e will be sufficient to elicit a depth response, which in turn will lead to a change in the apparent size of the T figures. However, once the size distortion is found, it is simple to find the conditions for misapplied perspective in the configuration. A similar analysis may also be applied to most of the other size-distortion explanations.

The exception is Howard's¹ explanation of the concentric-squares and related illusions. A careful consideration of the literature suggests that these illusions behave like figural aftereffects, if the distortions are assumed to occur along the attribute of size rather than location. The data presented above indicate that the concentric-squares illusion contains a size-distortion component. Thus, it is possible to take a slightly modified form of Ganz's (1966) model for figural aftereffects and to generate predictions about size-distortion illusions.

Most of the predictions are for phenomena which are analogous to those found in figural aftereffect experiments. There should be a distance paradox for illusions, as the relative lengths of the I and T lines are varied. The T lines should appear

shorter than they actually are, rather than longer, if the difference between the lengths of the I and T lines is very small or very great. Other predictions which can be made from the model involve the mutual distortion of the I and T figures, the effects of varying the contrast of the I and T figures, and their duration. We are currently simulating this model, with the intent of making explicit predictions about the behavior of the concentric-squares illusion under various temporal and spatial transformations. The technique described here for isolating size distortions from possible location distortions will provide the necessary data with which to test the model.

Finally, we would like to suggest that the technique employed in this experiment can be used to identify other size distortions. Blakemore & Sutton (1969) have suggested that figural aftereffects may also involve size distortions. This hypothesis can be tested quite simply for the concentric-squares configuration by presenting the I and T figures shown in Fig. 1 successively. The same method may be applied to other perceptual distortions, such as time and space errors, and apparent motion, which may involve either the attribute of size or location.

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NOTE

1. Howard, R. B. Neurophysiological models of figural aftereffects and visual illusions. In preparation. Prepublication copies of this paper are available from the author upon request.

Effects of ratio of win-stay to lose-shift problems on children's performance on win-stay problems*

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Statistical analyses combined data from a series of learning-set experiments with 4- and 8-year-old children (Berman, 1965; Berman, Rane, & Bahow, 1970). Two types of two-trial discrimination problems were presented: win-stay and lose-shift problems. The proportion of win-stay to lose-shift problems differed for four experimental groups. A significant win-stay practice effect was demonstrated when increasing numbers of win-stay problems were added to a constant number of nonreward problems. Two analyses tested the effect of adding lose-shift problems to a constant number of win-stay problems. The lose-shift problems significantly interfered with performance on win-stay problems.

In a series of learning-set experiments (Berman, 1965; Berman, Rane, & Behow, 1970), two types of two-trial discrimination problems were presented to children. A single stimulus was presented on Trial 1 and then again on Trial 2, paired with a new stimulus. When the Trial 1 stimulus was rewarded (win-stay or reward problems), the S was required to choose it again on Trial 2. When it was not rewarded (lose-shift or nonreward problems), he was required to choose the new stimulus on Trial 2. The proportion of win-stay to lose-shift problems given per day differed for four experimental groups. Group 25 was given 25% reward problems; Group 50, 50%; Group 75, 75%; and Group 100, 100%. The procedure was similar to that used by King & Harlow (1962) with monkeys.

When 4- and 8-year-old Ss had an equal number of problems of each type (Berman, Rane, & Bahow, 1970), they made significantly more errors on the win-stay problems. When the problems were given in unequal proportions (Berman, 1965), varied experience with the two problems only slightly affected performance on

the lose-shift problem but greatly affected performance on the more difficult win-stay problem. The effect of varied experience on win-stay performance may be due to either or both of two factors: positive transfer resulting from practice with the win-stay problem and negative transfer resulting from reward of shift responses which are correct on lose-shift problems but incorrect on win-stay problems. The present analyses test each of the two factors separately, while holding the other constant.

SUBJECTS

The Ss were 32 4-year-olds and 32 8-year-olds. Names of Ss were drawn from lists of children living in University of Wisconsin housing projects for faculty and graduate students, from registration lists of a recreation program of a nearby elementary school, and from two nursery schools. Children were selected randomly within age groups but were limited to children of graduate students, faculty members, and others with professional and managerial occupations. Four children failed to complete the series of experimental sessions, two due to illness and two because of reluctance to participate. They were replaced by others from the same age groups. Mean ages of the 4-year-old groups were: Group 25, 53 months; Group 50, 52

months; Group 75, 55 months; and Group 100, 53 months. Mean ages of the 8-year-old groups were: Group 25, 100 months; Group 50, 101 months; Group 75, 101 months; and Group 100, 101 months.

APPARATUS AND STIMULI

A simplified form of the Wisconsin General Test Apparatus (Harlow, 1959) was used. Stimuli were 288 stereometric "junk objects," varying in many dimensions, such as form, color, pattern, and material. Two new objects were used as stimuli for each two-trial problem, with stimuli presented in different randomly selected pairs and in a different order for each S. Stimuli were presented on a 5¼ x 17¼ in. tray, with three reward wells which were 6 in. apart from center to center.

PROCEDURE

Within each age group, eight children were chosen and assigned randomly to each of the procedural groups. Groups 25, 50, and 75 received 144 problems. Group 25 had 25% reward problems (6 reward and 18 nonreward problems per day for 6 days); Group 50 had 50% (12 reward and nonreward problems per day for 6 days); Group 75 had 75% (18 reward and 6 nonreward problems for each of 6 days). Group 100 had 108 reward problems only (24 problems per day for 4 days and 12 on the fifth day).

On Trial 1 of reward problems, a single object was placed over the center well of the tray. The well contained a small toy. On Trial 2, the same stimulus covered one of the side wells and its choice was again rewarded. It was paired with a new stimulus which covered the other empty side well. On nonreward problems, the same procedure was followed, except that the single stimulus presented on Trial 1 was not rewarded on either trial and the novel stimulus with which it was paired on Trial 2 was rewarded.

Each child was seen individually. On Trial 1 he was asked to see if the stimulus presented had a toy beneath it. On Trial 2 he was told, "One of these has a toy under it. Pick the one you think has a toy under it." After his choice, he was told, "Yes, the toy was under *that* one, wasn't it?" (or, "No, the toy was not under *that* one, was it?"). Twenty-four problems per day were presented for 6 days (4½ days for Group 100), or until the S met a criterion of correct responses to 10 consecutive reward problems and 10 consecutive nonreward problems.

The presentation order of reward and nonreward problems was determined randomly within restrictions designed to reduce long runs of either of the problems. Position of reward on Trial 2 was

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