A texture-contingent visual motion aftereffect*

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The following procedure produces a new motion aftereffect. Two visually textured disks—one fine and the other coarse—rotate in opposite directions, and the O fixates the center of each disk alternately for 4 sec. After 4 min of viewing, the disks are stopped. Each stationary disk, when fixated, then appears to rotate in the opposite direction from its prior objective rotation. This phenomenon, a texture-contingent negative motion aftereffect, is analogous in some respects to the McCollough effect, an orientation-contingent color aftereffect.

The visually textured rotating disks illustrated in Fig. 1 produce a new visual motion aftereffect. The disks rotate in opposite directions at 8 rpm in the frontal plane, and the disks are lighted alternately for 4 sec. The O fixates the center of each rotating disk while it is lighted, and after 4 min of viewing, the disks stop rotating. When the O then fixates each disk, the disk appears to rotate in the direction opposite to its prior objective rotation. Thus, opposite negative motion aftereffects occur when the same visual receptors are stimulated alternately by oppositely rotating fine and coarse visual textures. This phenomenon, a texture-contingent motion aftereffect, is analogous in some respects to the orientation-contingent color aftereffect discovered by McCollough (1965).

In the first demonstrations of the present phenomenon, the two disks were placed side by side a few feet in front of the O. After the inspection period, the fine and coarse stationary disks remained in the same left-right positions they had occupied during the inspection period. Since the directions of eye movements (left and right) required to fixate the rotating disks were correlated with directions of rotation, it could be argued that the direction of negative motion aftereffect might have been mediated by a conditioned relationship between left-right eye movements and possible cyclotorsional movements induced by the rotations of the disks. In order to rule out the above explanation, in the experiment described below, the left-right positions of the fine and coarse disks were interchanged after the inspection period.

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OBSERVERS

Eight men and eight women, introductory psychology students at the University of Missouri—St. Louis, participated as a course requirement.

APPARATUS

The visual textures were selected from a specially prepared set of quasirandom textures comprising a logarithmic scale. Regular dot arrays, such as printing screens, are readily available commercially, but irregular textures produce greater conventional motion aftereffects (Dixon & Meisels, 1966). An irregular master texture was prepared by placing a $\frac{1}{4}$ -in. dot inside each $\frac{1}{2}$ -in. square on a large white surface. The X-Y coordinates of each dot within its square were determined by choosing a pair of random digits from a table of random numbers. The black-white ratio of the master texture was .20, discounting the occasional partial overlap between neighboring dots. A set of textures was prepared by making successive photographic reductions of the master texture. Each texture differed in size by .1 log unit from adjacent textures, and the black-white ratio was constant for all textures within the limits of the photographic reproduction process. Thus, the visual textures varied along the fine-coarse dimension but were essentially constant on the dimension of brightness. The coarse texture chosen for this experiment was .1 log unit finer than the master texture and the fine texture was .9 log unit finer than the master. There was a difference of .8 log unit between the coarseness of the textures used in this experiment, and, thus, the coarse texture was 6.31 times as coarse as the fine.

The disks were 6 in. in diam and were presented perpendicular to S's line of sight at a viewing distance of 8 ft. Each disk was enclosed in a box with a large circular hole in the front. The boxes were placed side by side and were of such a size that the centers of the disks were separated by

a distance of 29 in. Each disk was mounted in a circular hole in a flat black background, and each was illuminated from the front by a 100-W slide projector with a circular aperture in the slide plane. The edges of each cone of projected light were lost in an annulus separating each textured disk from its surrounding background. In order to maintain constant illumination, each projector was powered by a constant-voltage transformer. The luminance of the white portion of the disks was 42.0 mL and the black portion was 16.7 mL, measured by a Macbeth illuminometer. The disks were rotated at 8 rpm by tachometer-feedback-controlled dc motors.

PROCEDURE

The experiment was run with the room lights off. The disks were alternately lighted for 4 sec each, and O was instructed to fixate the center of each disk as steadily as possible as long as the disk was lighted. During the inspection period, O was asked in which direction the disks were rotating in order to make sure O was capable of indicating directions of rotation. For half the Os, the fine disk was on the left and the coarse on the right, and these positions were reversed for the other Os. The left disk rotated clockwise and the right counterclockwise for half the Os, and these rotation directions were balanced across the positions of the fine and coarse disks. Positions and rotation directions were balanced with respect to each other and also with respect to the sex variable. After a 4-min inspection period, the disks were stopped. The projectors were turned off for about 1 min while the fine and coarse disks were interchanged. Both stationary disks were then lighted, and O was asked to fixate the center of each disk and to indicate the direction of apparent rotation. If either disk, or both disks, appeared stationary, the E said, "If I told you the disk on the left (right) really was rotating, which direction would you guess it to be rotating?" A similar forced-choice procedure has been used in connection with studies of the McCollough effect (Harris & Gibson, 1968). The projectors were turned off while the disks were again interchanged so that the fine and coarse disks occupied the same left-right positions they had occupied during the inspection period. The stationary disks were again lighted, and O indicated directions of apparent rotation, as above.

RESULTS

Texture-contingent negative motion aftereffects occurred. After the inspection period, each visual texture appeared to move in a direction

Fig. 1. (A) Fine visual texture, and (B) coarse visual texture. The textures shown here are the actual ones used in the experiment, even though the illustrated disks are reduced from the sizes actually used.

opposite to its prior objective rotation.

Aftereffect scores were found by the following procedure: A free choice of direction opposite to the prior objective rotation of a texture was given a value of +2, and a forced choice in this direction was given a value of +1. Free and forced choices in the same direction as the prior objective rotation were given values of -2 and -1, respectively, since these choices represent responses contrary to those expected if texture-contingent negative motion aftereffects were to occur. An O's aftereffect score is the sum of the above values, and since the stationary fine and coarse textures were presented twice to each O, aftereffect scores could range between -8 and +8 inclusive. The mean aftereffect score was 4.75, and this score is significantly different from zero ($t = 6.29$, $df = 15$, $p < .001$). However, the aftereffect scores for two Os were zero. Table 1 shows the distribution of aftereffect scores.

The mean aftereffect score, above, takes into account forced as well as free choices. In order to rule out any contamination from any possible forced-choice biases, aftereffect scores were found utilizing only the data from the first presentation of the stationary textures. Free choices at

this stage of the experiment were made before any forced choices had been made. Assigning values of +1 and -1, respectively, to those free choices which support and do not support the occurrence of a texture-contingent aftereffect yields a mean aftereffect score of .94 out of two possible, and this mean is significantly different from zero ($t = 4.39$, $df = 15$, $p < .001$).

The aftereffect scores found by combining free and forced choices were subjected to a three-way analysis of variance. The factors were sex, position of test textures (switched vs not switched with respect to left-right positions of inspection textures) and texture magnitude (fine vs coarse). There were repeated measures on the last two factors. There was no significant sex effect ($F < 1.00$). Since the within-Os error terms were not heterogeneous, these error terms were pooled as recommended by Winer (1962). The only significant effect was that of texture magnitude ($F = 6.98$, $df = 1/42$, $p < .02$). The mean aftereffect scores for the fine and coarse textures were, respectively, 1.75 and 3.00 out of four possible. Since these means differ from each other, and since the smaller mean differs significantly from zero ($t = 3.42$, $df = 15$, $p < .01$), it follows

that a texture-contingent negative motion aftereffect occurred in both textures.

DISCUSSION

The apparatus used in the present experiment required that Os move their eyes left and right in order to fixate the fine and coarse disks. The experimental procedure probably rules out any simple conditioning between left-right eye movements and cyclotorsional movements as an explanation of the texture-contingent motion aftereffect, but it would nevertheless be desirable to present the disks in such a way that no eye movements would be required. An improved apparatus, utilizing a two-way mirror, allows the disks to be presented alternately in the same portion of the visual field. Preliminary observations carried out using this new apparatus confirm the occurrence of the texture-contingent motion aftereffect.

The present phenomenon appears related in some respects to the McCollough effect (McCollough, 1965). In this latter effect, a display consisting, for example, of a grid of red and black vertical bars alternates with a display of green and black horizontal bars. After fixating these alternating displays for a few minutes, black and white vertical bars appear greenish, and black and white horizontal bars appear reddish. Thus, the McCollough effect can be described as an orientation-contingent color aftereffect. Motion-contingent color aftereffects have also been

Table 1
Distribution of Aftereffect Scores

Score	0	1	2	3	4	5	6	7	8
Frequency	2	0	3	2	1	0	0	4	4

described, where red-and-black and green-and-black moving stimuli produce color aftereffects when black-and-white moving stimuli are subsequently presented (Hepler, 1968; Stromeyer & Mansfield, 1970).

McCollough (1965) argued that her aftereffect could be explained by color adaptation of edge detectors, although no such color-sensitive edge detectors were known to exist at that time. While McCollough's explanation has been questioned (Harris & Gibson, 1968), orientation detectors have been found in the visual cortex of the monkey which respond to colors in an opponent-process manner (Hubel & Wiesel, 1968). Adapting a set of such color-sensitive orientation detectors simultaneously to color and orientation should produce not only orientation-contingent color aftereffects, but color-contingent orientation aftereffects as well, depending primarily on the arrangement of the test stimuli. Indeed, Held & Shattuck (1971) have recently produced a color-contingent orientation aftereffect which reverses the contingency relationship observed in the McCollough effect.¹

There is indirect evidence that texture-sensitive detectors may exist in the visual system, since inspecting a coarse visual texture makes a subsequently viewed intermediate

texture look finer (Walker, 1966; Blakemore & Sutton, 1969). There is also evidence that visual texture is a factor in the apparent velocity of objective motion and motion aftereffects (Cann, 1962; Walker²). If there are texture detectors in the visual system which are also responsive to motion, then such motion-sensitive texture detectors might account for the present texture-contingent negative motion aftereffect.

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NOTES

1. After this paper was accepted for presentation to the American Psychological Association, a color-contingent motion aftereffect closely analogous to the present texture-contingent effect was reported by Favreau, Emerson, & Corballis (1972); these writers referred to earlier unpublished observations of a color-contingent motion aftereffect by Stromeyer (1968) and also cited a paper by Mayhew & Anstis (1972) reporting color- and texture-contingent motion aftereffects.

2. Walker, J. T. Some effects of visual texture on real and apparent visual motion. In preparation.