Phantom spiral aftereffect: Evidence for global mechanisms in perception

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The existence of phantom motion aftereffects (MAEs) makes it difficult to explain normal MAEs in terms of the activity of simple motion detectors. The alternative is to assume that MAEs are mediated by larger structures that respond more broadly to stimulus input. In this view, normal and phantom MAEs are manifestations of activation of a single structure and, therefore, should not differ in their qualitative and quantitative properties. This hypothesis was tested in two experiments, one that used experienced subjects and one that used naive subjects. The adapting stimulus was the upper half of a rotating spiral. Normal spiral aftereffects (SAEs) were observed over the upper half of a set of concentric circles; phanton SAEs were observed over the lower-half semicircles. Subjects continuously rated the strength of the aftereffect on an 11-point scale. The ratings were recorded every 5 sec. All subjects reported seeing normal and phantom SAEs in the appropriate respective directions. Rates of recovery from adaptation were remarkably similar. The results support the hypothesis that normal and phantom SAEs are a manifestation of activity in a structure larger than a simple motion detector.

Motion aftereffects (MAEs) are usually explained in terms of the activity of motion detectors, structures that are directly sensitive to stimulation in specific retinal locations (Barlow & Hill, 1963; Erke & Graser, 1972; Sekuler & Pantle, 1967; Sutherland, 1961). In this conception, the detector units are independent, implying that MAEs should be observed only over the region of the visual field that contained the stimulation. MAEs seen over regions of the visual field adjacent to those receiving stimulation (Bonnet & Pouthas, 1972; Goldstein, 1958; Weisstein, Maguire, & Berbaum, 1977) are called phantom MAEs. The existence of phantoms makes it difficult to explain normal MAEs in terms of the activity of simple motion detectors (Weisstein et al., 1977).

One alternative to the motion detector conception is to assume that motion perception and MAEs are mediated by structures that process inputs more globally. If the entire structure is activated by stimulation of a portion of its receptive field, then phantoms could be explained as the manifestation of this activity in a portion of the structure that corresponds to an unstimulated area of the visual field. A number of structures of this sort have been proposed. Regan and Beverley (1978a, 1978b, 1979; Beverley & Regan, 1979; Regan, 1982) suggested global input mechanisms for detecting changing size and motion in depth, and Cavanagh and Favreau (1980) suggested a global mechanism for detecting rotation. Presumably, these structures feed information to the perceptual system.

A second alternative is to assume that the perceived motions and the MAEs reflect the structure of the subsystems within the perceptual system itself. Hershenson (1982) proposed one such subsystem, the loom-zoom system, that mediates directly the perception of size and motion in depth. In this conception, a single perceptual subsystem processes expansion and contraction in the proximal stimulus to produce, in normal perception, perceived size constancy and motion in depth. Repeated stimulation by an expanding or contracting stimulus produces a contracting or an expanding MAE, respectively. Depending on the kind of test stimulus used, the MAE may contain motion in depth and size change. Hershenson suggested further that the spiral aftereffect (SAE) and the moon illusion were manifestations of the activity of this perceptual subsystem.

Clearly, the global-mechanism hypothesis would be on firmer ground if phantom and normal MAEs were found to have similar qualitative and quantitative properties. The rate of recovery from adaptation is one quantitative property that is relatively easy to measure and has a history of use as a fundamental property by which to distinguish among hypothetical structures (Beverley & Regan, 1979; Favreau, 1981). This report describes two experiments that compared the qualitative and quantitative properties of normal and phantom SAEs using adaptation times that were long enough for the mechanism(s) that produced the SAEs to be operating close to saturation. In Experiment 1, experienced observers adapted for 5 min on the initial trial and for 3 min on the remaining two trials in each condition; in Experiment 2, naive observers adapted for 3 min on the initial trial and for 1 min on the remaining two trials in each condition.

The adapting stimulus used in both experiments was the upper half of a rotating Archimedes spiral, a stimulus with

a large radial-motion component (Milligan & Scott, 1971; Scott & Noland, 1965) that produces a phantom SAE over a lower-half test stimulus (Bonnet & Pouthas, 1972). The test stimuli were the upper and lower halves of a set of concentric circles, patterns that evoke strong radial (expansion/contraction) SAEs after such a rotating spiral has been viewed.

Normal SAEs were observed against the upper-semicircles test stimulus, and phantom SAEs were observed against the lower-semicircles test stimulus. This combination of adaptation and test stimuli had the unique feature of providing differential predictions with respect to the directions of motion of the normal and phantom SAEs. Specifically, an expanding half-spiral produced perceived motion *downward* and inward toward the center of the semicircles for the normal SAE, and perceived motion *upward* and inward for the phantom SAE. Similarly, a contracting half-spiral produced an *upward* and outward perceived motion for the normal SAE and a *downward* and outward perceived motion for the phantom SAE.

EXPERIMENT 1

Method

Subjects. The two subjects were experienced observers who had spent many hours in perception experiments. One (J. W.) understood the theoretical context of the experiment, and the other (C. F.) was acquainted with MAEs but did not know the specifics of the experiment.

Stimuli. The adapting stimuli were the upper halves of left- and right-throw 720° Archimedes spirals produced by a black line 1 cm thick on a white disk that subtended approximately 3.3° of visual angle. Adapting stimuli rotated at approximately 60 rpm in front of a white background. The test stimuli were two sets of five concentric black semicircles drawn on white paper. Each line was approximately 2 mm thick. The circles were spaced evenly over an area subtending approximately 3.3° of visual angle. The entire stimulus field was illuminated by two 75-W floodlights 150 cm from the plane of the stimuli.

Procedure. The subject's head was held relatively immobile by a chin and head holder. The adapting stimulus was viewed through an aperture measuring 4° horizontally and 6° of visual angle vertically. The occluding panel contained a sliding door that exposed the adapting stimulus field when in one position and the test field when in the other position. The subjects fixated the small red circle at the center of rotation of the half-spiral with the right eye and, when the signal was given, shifted fixation to the center of the semicircles test stimulus. The shift was accomplished in less than .25 sec. The subjects adapted to the upper half of expanding and contracting spirals and were tested with upper and lower semicircles. The four adaptation-test stimulus combina-

tions were counterbalanced across subjects. Each combination was measured three times: after 5 min of adaptation on the first trial of each new combination and after 3 min of adaptation on the remaining two trials. A series of tests with a rotation aftereffect was interpolated between changes in direction of rotation of the spiral.

The subjects were told that the semicircles test stimuli might appear to be stationary or in motion. They were not told what direction the motions might take. The possibility that they might see no motion in some of the conditions was repeated a number of times. If they saw motion, they were to rate the strength of the motion on an 11-point scale, on which 10 represented motion as strong as that of the rotating spiral and 0 represented no motion. Immediately upon shifting fixation to the test stimulus, the subjects began calling out rating numbers and continued until zero motion was reported twice in a row. Judgments were recorded every 5 sec. After each trial, the subjects described the direction of SAE motion in their own words. Within the same rotation-direction/test-stimulus block, the subjects shifted fixation back to the adapting stimulus immediately after reporting zero motion in the test stimulus. Approximately 3 min elapsed between blocks.

Results and Discussion

After adapting with a contracting spiral, both subjects reported seeing the upper semicircles expand upward and outward (a normal SAE) and the lower semicircles expand downward and outward (a phantom SAE). After adapting with an expanding spiral, they reported seeing the upper semicircles contract inward and downward (a normal SAE) and the lower semicircles contract inward and upward (a phantom SAE). In all conditions, both subjects reported SAEs immediately upon shifting fixation to the test stimulus. There were no reports of seeing a phantom lower portion of the spiral during the adaptation period.

The log of rated SAE strength declined linearly as a function of time after adaptation. The slopes and standard errors of least-squares regression lines calculated separately for each subject in each condition are given in Table 1. Table 1 also contains the percentages of variance explained, the decay time constants calculated from the regression lines, and the corresponding standard errors. Within conditions, phantom and normal SAEs appear to be quite similar in both slope and decay time constant.

After relatively long adaptation periods, phantom and normal SAEs were qualitatively similar in that they manifested the appropriate (but different) respective directions of motion, and were quantitatively similar in terms

Table 1
Slopes of Least-Squares Regression Lines, Standard Errors (SEs) of Regression Coefficients,
Percentages of Variance Explained by Regression Lines (r², Decay Time Constants, and
Standard Errors (SEs) of Estimate for Expanding and Contracting Normal and
Phantom SAEs, for Two Experienced Subjects

Subject	SAE Direction	SAE Type	Slope	SE	r²	Decay Time Constant (sec)	SE (sec)
C.E.	Expand	Normal	−.94	.02	83	17.4	4.9
		Phantom	−.93	.05	59	13.2	5.7
	Contract	Normal	−.95	.02	72	18.2	5.4
		Phantom	−.93	.04	60	14.1	4.9
J.W.	Expand	Normal	−.90	.04	88	9.4	2.1
		Phantom	−.89	.04	89	8.4	1.6
	Contract	Normal	−.85	.05	92	6.2	1.4
		Phantom	−.85	.03	96	6.2	1.0

of their time course of recovery from adaptation. Thus, the data support the hypothesis that normal and phantom SAEs are manifestations of activation in different parts of the same structure.

EXPERIMENT 2

Experiment 1 might be criticized because the measurements were produced by knowledgeable observers. It might be argued that their responses were biased to produce similar decay functions for the normal and phantom SAEs. Experiment 2 was performed to control for this possibility. The subjects in this experiment had no knowledge of MAEs or of the implications of their responses.

Method

Subjects. The subjects were four undergraduate students at Brandeis University. They were not aware of the purpose of the experiment. When questioned after the experiment, none could remember having seen a MAE in a previous class.

Procedure. The stimuli and procedures were the same as in Experiment 1 except for two changes. First, adaptation times were decreased to 3 min for the first exposure and 1 min for the remaining two trials in a condition. These values were selected in pilot studies to be long enough to produce a strong phantom SAE and short enough to be tolerated by the untrained subjects. Second, the rotation aftereffect was not included, but approximately 10 min elapsed between blocks when the direction of rotation of the spiral was changed.

Results and Discussion

In all conditions, all subjects reported seeing SAE movement in the appropriate respective directions. All subjects reported seeing SAEs immediately upon shifting fixation to the test stimulus. There were no reports of seeing phantom spirals during the adaptation period.

The log of rated SAE strength declined linearly as a function of time after adaptation. Regression lines fit by the method of least squares for averaged rated SAE strength had slopes of $-.91$ and $-.92$, with a standard error of .03 for normal and phantom SAEs, respectively. The regression lines explained 93% and 94% of the variance, respectively. Decay time constants calculated from the regression lines were 10.5 and 12.1 sec, with standard errors of estimate of 2.8 and 2.2 sec for normal and phantom SAEs, respectively. Once again, the data suggest no differences between normal and phantom SAEs.

GENERAL DISCUSSION

Experienced and naive subjects described normal and phantom SAEs that were qualitatively similar in their respective directions of motion.

Recovery from adaptation, indexed by the slopes of regression lines and decay time constants calculated from the lines, showed remarkable similarity between normal and phantom SAEs within conditions. These results support the hypothesis that normal and phantom SAEs are manifestations of the activation produced by the initial stimulus in a structure larger than a simple motion detector. Whether such a structure processes input that is then fed to the perceptual system (Regan, 1982) or constitutes a subsystem of the perceptual system whose activity results directly in perceptual experience (Hershenson, 1982) cannot be determined from these results. Nevertheless, these ideas now require more serious consideration.

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