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The effect of prolonged practice of pursuit eye movement

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Prolonged exposure to a reciprocating motion that is tracked by the eyes results in diminished extent of perceived motion. Investigation of this effect showed that it becomes manifest only in perceived motion that is caused by ocular pursuit, but that it is not an eye muscle effect. It may consist in a changed evaluation of eye movements. The results throw some light on the relations between the processes that are caused by different stimuli for motion.

When a subject observes a reciprocating linear motion for 5 min or longer, pursuing the moving object with his eyes, the apparent extent of the motion path will become smaller. If such an inspection period lasts 10 min, the decrease in the length of the perceived motion is 15% or more. We discovered this effect while performing further experiments on adaptation in motion perception of the sort described by Wallach, Bacon, and Schulman (1978). The following report presents the results of our probing into the nature of this pursuit eye movement (PEM) effect. In the course of our investigation, we employed two different tests for measuring the PEM effect.

EXPERIMENT 1

The PEM Effect Measured by Estimating the Tilt of a Resultant Motion

This test compares the extent of a perceived motion that results from ocular pursuit with the extent of an induced motion that results from object-relative displacement.[1] Such a test had been used previously by Wallach et al. (1978) to measure changes in induced motion. Here it was employed to measure changes in the effectiveness of ocular pursuit.

When a moving target is seen against a stationary patterned background and is tracked by the eyes, the perceived motion results from two different conditions of stimulation—object-relative displacement and ocular pursuit. These two stimuli for motion perception cooperate here toward the same result. But when the moving target is seen against a background that also moves, the two stimuli will be in conflict, because the object-relative displacement will now tend to cause a nonveridical perceived motion.[2] If, for instance, the real motion of the target is vertical and the motion of its background is horizontal, the target's displacement relative to its background is oblique, and that is the motion that is perceived on object-relative grounds. Ocular pursuit, on the other hand, would normally cause the real vertical motion to be perceived, but because object-relative displacement is here much the more potent stimulus, ocular pursuit appears to have no influence at all on what is being perceived.

To enable ocular pursuit to make itself felt, the vertical motion of the target, a light spot, should not be given as objective-relative displacement. To achieve this, a background is needed that offers no landmarks for a vertical displacement of the light spot. Such a background consists of a pattern of vertical lines whose ends are beyond the boundaries of clear vision and therefore not perceived. When such a background moves horizontally, any motion direction that has a horizontal component in the sense opposite to the motion of the background is compatible with the light spot's displacement relative to the lines, for a line pattern does not define an object-relative displacement of one particular direction. The reason is that the line pattern provides no landmarks relative to which a vertical component of the spot's displacement could become manifest, and object-relative displacement defines here not a single motion direction

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but an array of motion directions, all of which have a horizontal component with a sense opposite to that of the motion of the pattern. Which of these potential directions will actually be seen depends on what is subject-relatively given. If the light spot is stationary, the perceived direction will be horizontal, but if it moves vertically, motion in some oblique direction will be perceived. The tilt angle of this perceived motion depends, in the first place, on the extents of the two component motions—the horizontal motion caused by the motion of the line pattern and the objective vertical motion of the spot. The tilt angle also depends on the relative effectiveness of the stimuli that mediate the two motions. It can therefore be used to measure a change in the effect of ocular pursuit.

Method

The apparatus used by Wallach et al. (1978) was used. The vertical line pattern was visible on a screen 80 cm high × 50 cm wide and made of white translucent plastic. The lines were .8 mm wide and 2.5 cm apart. The base of the screen could be moved back and forth in a slot by a device that provided simple harmonic motion. A spot of light 5 mm across was projected on the screen from the rear by a small projector mounted inside a tube. The spot was given its reciprocating vertical motion by tilting the projector up and down. The motion of the projector was coupled to the motion of the screen and was therefore also simple harmonic motion. Both motions started their excursions simultaneously; only the extents of their motions could be varied. The subject, in a headrest, observed the arrangement from a distance of 34.5 cm. The screen was illuminated from the rear by a shielded source. Except for this source and a lamp that was turned on when the subject gave a tilt estimate, the room was dark. A tilt estimate was given by adjusting the slope of a rod whose orientation in a vertical plane could be changed. In all experiments to be reported, the motion speed was quite moderate; a single excursion was 15 cm long and took 3 sec. The peak velocity was 7.5 cm/sec.

The tilt estimates we obtained in this experiment represented the apparent motion direction of the vertically moving spot. As was explained, this motion direction was the resultant of two perceptual processes, one caused by the ocular pursuit of the objective motion of the spot and the other by the object-relative displacement between the spot and the moving pattern of vertical lines. Wallach et al. (1978) used this apparent motion direction to measure changes in the effectiveness of object-relative displacement after prolonged exposure to induced motion. When this effectiveness diminished, the tilt angle of the resultant perceived motion, the angle it formed with the vertical, became smaller, because the horizontal motion component had become diminished. We used this tilt angle to measure changes in the effectiveness of the ocular pursuit of the vertical motion. A diminished effectiveness resulted in an increase of the tilt angle.

In the tests of Experiment 1, the excursion of the screen was 8.7 cm, while the excursion of the vertically moving spot was 15 cm. The resultant of the vertical objective motion of the spot and of its horizontal objective-relative displacement formed an angle of 30.1 deg. First, the subject, who was instructed to keep his eyes on the spot, gave four estimates of the tilt of the direction of this motion. The average of these four estimates became the subject's preexposure score. Then the movement of the screen was halted, and the subject was asked to follow the moving spot with his eyes. This exposure to continuous PEMs lasted 10 min. Then the screen was again set in motion, and the subject gave four further tilt estimates. Twenty paid undergraduates served as subjects.

Results

The mean tilt estimate before exposure was 33.8 deg. The object-relative displacement between the spot and the screen was apparently fully effective. After exposure, the mean tilt estimate was 39.1 deg. The difference between the two means was significant [$t(19) = 3.46$, $p < .005$]. This change in the mean tilt estimate means that after exposure the vertical motion of the spot was underrated by 17.6% [(cot 33.8 deg − cot 39.1 deg)/cot 33.8 deg].

EXPERIMENT 2

The PEM Effect Measured by Estimating the Tilt of a Real Motion

In this test, the subject gave estimates of the tilt of a real oblique motion.

Method

A light spot was projected from the rear on a homogeneous translucent screen and underwent a reciprocating simple harmonic motion whose path formed an angle of 43 deg with the vertical and was 15 cm long. The exposure period during which the PEM effect developed was identical to the exposure in Experiment 1. The subject tracked a vertical reciprocating motion of the spot, which was 15 cm long, for 10 min. It was presented on a different screen, which was located beside and at right angles to the test screen. A headrest kept the subject's eyes at a distance of 34.5 cm from either screen. During the tests and during the exposure period, the room was completely dark; the test rod was illuminated only when the subject gave his tilt estimate. There were, therefore, no landmarks for the motion of the spot when the subject tracked it. Twelve paid undergraduates served as subjects.

Results

The mean tilt estimate for the test motion was 42.5 deg before exposure and 47.2 deg after exposure, and this change was highly significant [$t(11) = 5.79$]. The change in the mean tilt estimate indicates that after exposure the vertical component of the oblique motion path was underrated by 7.8%. When we made the results of this test comparable to the result of Experiment 1 by computing the change in the vertical component on the cotangent scale, we find that the exposure period diminished the vertical component of the estimated motion direction by 14.7% [(cot 42.5 deg · sin 42.5 deg) − (cot 47.2 deg · sin 47.2 deg)/cot 42.5 deg · sin 42.5 deg].

The experiment was repeated with the motion that was pursued during the exposure period in horizontal orientation. A corresponding result was obtained. After the exposure period, the horizontal component of the test motion was diminished and the mean tilt estimate was steeper. It was 37.8 deg before and 33.3 deg after exposure, and the implicit shortening of the horizontal component was 10.4%.

When it was measured as a tilt of a real oblique motion, the effect of a 10-min exposure to vertical PEMs was 14.7%, nearly the same as when it was measured in Experiment 1 as the tilt angle of a resultant motion, when the PEM effect had amounted to 17.6%. We infer from this that the PEM effect was largely restricted as to direction. If it were not, it would have also affected the test motion in the present experiment that differed from the exposure motion by 45 deg, and this would have diminished the PEM effect measured with the oblique motion.

The outcome of Experiment 2 also shows that the PEM effect can diminish a component of a test motion. When, for instance, a PEM effect for vertical motion was brought about, the extent of the vertical component of the oblique test motion was diminished, and its tilt angle became larger. This fact would be readily understood if the PEM effect resulted from the prolonged use of one pair of eye muscles during the tracking movement of the exposure period. This explanation is, however, ruled out by the result of our next experiment.

EXPERIMENT 3

Does the PEM Effect Result from the Prolonged Use of Eye Muscles?

Here we asked whether the PEM effect results from performing eye movements during the exposure period, no matter what their function, or whether it is necessary that the eyes pursue a moving target. We replaced pursuit movements with compensatory eye movements that are caused by head movements for which they compensate. The subject continuously nodded his head up and down while he fixated a stationary spot. By limiting the extent of the head movements, the eye movements necessary to keep the eyes on the stationary spot were made to resemble the pursuit movements that were made in the exposure period of the previous experiments.

Method

The subject wore a helmet to which a vertical rod was attached. When the subject alternately raised and lowered his head, the end of the rod moved back and forth between two stops that allowed the right amount of head movement. The subject completed 10 to 12 head movement cycles per minute so that the frequency of the head movements was close to the frequency of PEMs in the previous experiments, which was 10 per min.

The resultant motion test of Experiment 1 was used. It is better suited to the purpose of the present experiment, because the eye movements that are made in the resultant motion test have the same direction as those made in the exposure, whereas the eye movements of the real motion test have only a component in common with exposure eye movements. Two different forms of the test were used. In the case of 10 subjects, the test was the same as in Experiment 1; the excursion of the screen was 8.7 cm. Another 15 subjects were tested with a screen excursion of 15 cm.

Results

The mean preexposure tilt estimates amounted to 37.9 and 47.8 deg, and the postexposure means did not change toward larger tilt angles, that is, in the direction of a PEM effect; they were 36.5 and 46.9 deg, respectively. Although the eye muscles were used in this exposure period in about the same manner as in the previous experiments, no PEM effect developed. The mere practice of the kind of eye movements that occur in ocular pursuit is not sufficient to produce the PEM effect.

As stated, the motion of the spot that the eyes tracked in Experiments 1 and 2 was simple harmonic motion. The relative displacements between the fixated stationary spot and the eyes produced by the head movements also accelerated with each excursion and became slower at its end, but it was somewhat more nearly of constant speed than the simple harmonic displacement that was given by the real motion of the spot. The following experiment incidentally showed that such differences did not matter.

EXPERIMENT 4

Can the PEM Effect Be Prevented by Having Image Displacements Precede the PEMs?

In this experiment, the subject pursued a horizontally moving spot with his eyes, but there were two changes. Constant-speed motion was used instead of simple harmonic motion, and a period of variable duration was introduced between excursions during which the spot was stationary. These changes were made for the following reason. Under ordinary circumstances, pursuit eye movements are preceded by a brief period during which the motion of the object is given as a displacement of the object's retinal image. Only after the direction and the speed of the given motion have been sampled as an image displacement do the eyes take up pursuit (Robinson, 1965). In the regular reciprocating motion, which produced the PEM effect in Experiments 1 and 2, the initial periods of image displacement dropped out rapidly and pursuit movements started without delay. We felt it necessary to show that the PEM effect was not restricted to such special conditions. To restore an initial image displacement to the pursuit movement in the exposure period, the motion of the spot was stopped for a varying time interval at the beginning of each excursion. At the same time, we changed its simple harmonic motion to one of constant velocity.

Method

The mechanism that moved the spot horizontally with simple harmonic motion was replaced by a horizontal cam, on which rode a springloaded pin. This pin was set into the end of a lever. The other end of the lever was connected to a horizontally movable carriage on which the projector for the spot was mounted. The cam was shaped to give the carriage a reciprocating motion of constant velocity. The shaft of the cam was joined to the output shaft of a magnetic clutch-and-brake, which, in turn, was mounted on the vertical slow shaft of a reduction gear motor. A microswitch was mounted at each end of the excursion of the carriage. These switches were inserted in series into the circuit of the clutch. When the carriage reached the end of an excursion and engaged a switch, the clutch circuit was interrupted and the simultaneous breaking of the output shaft of the clutch stopped the cam's rotation. The interruption of the clutch current could be overridden by a switch manipulated by the experimenter. By pushing it, the experimenter could cause the clutch to engage, the cam to resume its rotation, and the light spot to start another excursion. The duration of the pause between successive excursions was varied randomly between approximately .5 and 2.5 sec. The speed of the motor was set so that each excursion took 3 sec, as before. The real motion test of Experiment 2 was used, the angle of the tilted path was 43 deg, and 10 subjects participated.

Results

The mean tilt estimate before exposure was 32.8 deg, after exposure it was 27.1 deg, and the difference was significant [$t(9) = 3.74$, $p < .01$]. The horizontal component of the mean tilt estimate was 15.9% shorter after exposure than before. Thus, the usual PEM effect was obtained when the spot's motion was of constant velocity and when each excursion of the moving spot started after a variable time interval during which the spot remained stationary. This caused each pursuit movement to start only after an initial image displacement had taken place.

EXPERIMENT 5

Does Prolonged Motion Perception That Is Caused by Image Displacement Result in a PEM Effect?

We are now returning to the result of Experiment 3 that had shown that compensatory eye movements did not bring about a PEM effect. It was concluded that the mere occurrence of the kind of eye movements that take place in ocular pursuit do not produce our effect. Rather, the observer must be viewing a moving object. We therefore asked what psychological processes that occur during pursuit of a moving object may be responsible for the PEM effect. Is a prolonged perception of the same reciprocating motion responsible? In that case, it should not matter what conditions of stimulation produce the perceptual process that is altered. To test for this possibility, we exposed subjects to the same continuous reciprocating motion that in the previous experiments was represented by ocular pursuit and caused it to be given by image displacement.

Method

A stationary mark, which the subject fixated throughout the 10-min exposure period, was added to the display adjacent to the path of the vertically moving spot. We measured the effect of this exposure with the resultant motion test. The horizontal excursion of the vertical line pattern was here equal to the vertical motion of the tracked spot—namely, 15 cm. Twelve subjects participated.

Results

The exposure to prolonged vertical image displacement produced no effect. The mean tilt estimates were virtually unchanged by the exposure. The mean tilt estimate was 47.8 deg before exposure and 48.5 deg after exposure [$t(11) = .338$]. The prolonged perception of reciprocating motion did not alter the extent of a pursuit eye movement.

The following experiment shows that a PEM effect caused by tracking does not manifest itself in a change of a motion based on image displacement.

EXPERIMENT 6

Does the PEM Effect Change a Motion That Is Given by Image Displacement?

Here we tested a normally produced vertical PEM effect with the resultant motion test of Experiment 1 that was so altered that the motion of the spot was given as image displacement instead of being tracked.

Method

A mark was added to the horizontally moving pattern just below the lower end of the spot's vertical motion path and aligned with that path when the pattern was at the midpoint of its excursion. Keeping the eyes on this mark amounted to tracking the horizontal motion of the pattern instead of the vertically moving spot. As in the normal resultant motion test, the subject saw the spot moving obliquely and gave tilt estimates of its motion direction. The excursions of the spot and of the line pattern were both 15 cm. In the exposure period, the subject tracked a reciprocating vertical motion of the spot for 10 min. Twelve subjects participated.

Results

No effect of the prolonged exposure to PEMs was measured. The mean tilt estimate before exposure was 46 deg, and after exposure it was 45.2 deg. The small difference, which was not significant [$t(11) = .453$], was in the direction opposite to the change a PEM effect would have produced.

This modified resultant motion test had previously been used by Wallach et al. (1978). Because the resultant oblique motion of the spot is given here as an oblique image displacement—the resultant of the vertical displacement of the spot's image due to its objective vertical motion and the horizontal displacement of its image due to the horizontal eye movement—the authors proposed alternative interpretations of the test. In one interpretation, position constancy first compensates for the horizontal component of the image displacement and causes it to be represented at a higher level as vertical. Then the perceived oblique motion is formed as the resultant of that vertical displacement and of the horizontal relative displacement between the spot and the line pattern (i.e., the spot's induced motion). The other interpretation questions whether position constancy operates, when the object whose image is displaced due to an eye movement has a motion of its own, in as much as position constancy would deal here with a component of the given image displacement. Instead, the interpretation assumes that the perceived oblique motion results directly from the oblique displacement that the spot's image undergoes. Either of these interpretations is compatible with the purpose of our test. If the PEM effect altered motion perception based on image displacement, it would have affected a tilt of the perceived resultant as well as a perceived tilt based on the oblique image displacement. The fact that it did not shows that the PEM effect does not influence motion perception based on image displacement.

Interesting results are obtained when the PEM effect is tested with a motion that, in addition to being tracked, is also given by an object-relative displacement or when conditions that give rise to object-relative displacements are present during the PEM exposure.

EXPERIMENT 7

Does Simultaneous Presence of Object-Relative Displacement Interfere with Measuring a PEM Effect?

When, under induced-motion conditions, object-relative displacement is in conflict with ocular pursuit, the former prevails, provided induced motion is caused by an extended pattern. As has been reported in the introduction to the resultant motion test, object-relative displacement accounts for perceived motion under these conditions. Would that dominance of object-relative displacement be manifest also when we test for a PEM effect in the presence of an extended pattern?

Method

During exposure, the subject's eyes tracked a reciprocating horizontal motion for 10 min. The apparatus described in Experiment 4 was used; that is, the excursions of the spot were of constant speed, but the pauses before the start of the excursions were omitted. The PEM effect that would develop here was tested with the real tilt estimation method described in Experiment 2. As before, the motion of the test spot formed an angle of 43 deg with the vertical. This obliquely moving spot was projected on the screen with the vertical line pattern that we ordinarily used in the resultant motion test described in Experiment 1. In the present experiment, the screen was stationary and served as a framework for the horizontal component of the oblique motion of the spot. Thus, this horizontal component was given twice, as a component of the oblique motion of the spot that was given by PEMs and as displacement relative to the vertical line pattern. Without the line pattern, the results of Experiments 2 and 4 would have been obtained. Because the PEM effect diminishes the horizontal component of the motion of the tracked spot, this motion should have formed a smaller angle with the vertical after exposure than before. But this result was not obtained with the vertical line pattern visible in the test.

Results

Eleven subjects gave a mean tilt estimate of 38.6 deg before exposure and 38.7 deg after exposure, with the confidence interval at the 95% level of 3.3 deg.

Two conclusions can be drawn from this failure of the PEM effect to change the motion direction perceived in this test: (1) The PEM effect does not influence motion perception that results from object-relative displacement. If it did, the angle of the mean tilt estimate would have been smaller after exposure than before. (2) The object-relative condition of stimulation dominated the perception of the objective motion as far as its horizontal component was concerned, so that the horizontal PEM effect did not make itself felt. This second conclusion only confirms what we know from experiments in which a cue conflict exists between the two stimulus conditions, object-relative displacement that leads to induced motion and pursuit eye movements. There, too, the former prevails.

EXPERIMENT 8

Does Addition of Object-Relative Displacement Prevent the Formation of the PEM Effect?

In this experiment, object-relative conditions for motion perception were added to the PEMs performed during exposure, and the question raised was whether they would prevent the development of the PEM effect.

Method

The subject tracked, for 10 min, a spot in reciprocating vertical motion that was visible on a pattern of horizontal lines .8 mm wide and 2.5 cm apart. The resultant motion test of Experiment 1 was used, from which the horizontal lines were, of course, absent. Eleven subjects participated.

Results

A strong PEM effect was measured here. The mean tilt estimate was 33.1 deg before exposure and 40.9 deg after exposure, a change that amounted to 24.7% and was highly significant [$t(10) = 4.43$, $p < .005$].

While the results of the previous experiment indicated that the PEM effect does not influence motion perception that results from object-relative displacement, having motion that is given by PEMs simultaneously given by object-relative displacement does not prevent the PEM effect from developing.

This ends our analysis of the PEM effect. The last experiment provides data about its temporal course.

EXPERIMENT 9

Dissipation and Rate of Acquisition of the PEM Effect

We obtained rough measurements of the growth of the PEM effect with increasing exposure time. Earlier, we had done an experiment that showed that the PEM effect dissipates rapidly. The effect was obtained for vertical motion, and the resultant motion test was used.

Method

Before the postexposure test was given, the subject sat quietly for 5 min with closed eyes. The 12 subjects who participated gave a mean tilt estimate of 52.9 deg before exposure and one of 51.5 deg at the end of the dissipation period. The insignificant difference of 1.4 deg was in a direction opposite to one that a PEM effect would produce. This rapid dissipation of the effect made it possible to test the same group of subjects after four exposure periods of different length. Each postexposure test was followed by a dissipation period. Six of our 12 subjects gave a set of tilt estimates before a 2.5-min exposure and one immediately after it and then sat quietly with closed eyes for 7 min. The next exposure period, which was also preceded and followed by tilt estimates, lasted 5 min. After another 7-min dissipation period, a PEM effect was produced by a 10-min exposure and measured in the same fashion, and this sequence was repeated with an exposure lasting 20 min. The reciprocating motion that the subject tracked during exposures was vertical and simply harmonic, and the resultant motion tests of Experiment 1 were used. For the other six subjects, the order of the exposure periods was reversed; they were first given the exposure period of 20-min duration and ended with the 2.5-min exposure period.

Results

The results of this experiment are given in Table 1, which lists the mean tilt estimates that were given after the exposure periods of different length. The four preexposure tilt estimates that were given throughout the experiment were combined; they averaged 43.3 deg. The PEM effect rose from a 7% implicit underrating of the vertical component after the 2.5-min exposure to one of 16% after the 20-min exposure.

The results of this experiment also yield further evidence for the rapid dissipation of the PEM effect. The following data show the effect of the dissipation period connected with the 10-min exposure period. The mean tilt estimate before the 10-min exposure amounted to 43.8 deg. This mean changed to 46.1 deg after exposure and was back at 41.9 deg after the subsequent dissipation period of 7-min duration.

SUMMARY

The PEM effect was measured in two test conditions. In one of them, estimates of the tilt angle of an oblique motion path were made that were the resultant of two component motion processes, one based on object-relative displacement and the other given by ocular pursuit and thus subject to the PEM effect. In the other test, the subjects gave estimates of the tilt angle of an objective oblique motion, one component of which was altered by the PEM effect.

The PEM effect could be produced with continuous simple harmonic motion as well as with constant speed motion that started from target immobility of variable duration. No PEM effect developed when eye movements were caused by head nodding while the subject kept his eyes on a stationary spot, that is, when compensatory eye movements were performed. We conclude that the PEM effect does not result from prolonged use of eye muscles or from any other process phase that pursuit and compensatory eye movements have in common. It is likely that the PEM effect consists of a changed evaluation of pursuit eye movements.

Changed evaluation of PEMs is known to take place in another context—namely, as part of adaptation in the constancy of visual direction, as Wallach and Bacon (1977) have shown. It is also possible that an underrating of the extent of reciprocating motion is responsible for the diminished apparent size of the circular path of a moving light seen against a dark background. (A circular motion is the resultant of two reciprocating simple harmonic motions whose directions differ by 90 deg and that are combined with a 90-deg phase shift.) Coren, Bradley, Hoenig, and Girgus (1975) found that this size effect is related to smooth pursuit movements. It occurs at speeds higher than the one we used; our resultant motion test showed that, prior to exposure, pursuit movements represented the extent of objective motion correctly. Whether reciprocating motion of high speed is responsible for the size effect or whether the size effect occurs only when curved motion is tracked and is therefore unrelated to straight pursuit is an open question.

That the PEM effect consists of a changed evaluation of pursuit eye movements is in agreement with our other findings. Prolonged exposure to an objective motion that was given as image displacement did not produce the effect, and a properly produced PEM effect did not alter a motion that was given as image displacement. The PEM effect failed to affect perceived motion of a tracked object whose motion was also given by object-relative displacement. However, when, during exposure, motion was given by object-relative displacement in addition to being given by pursuit movements, the PEM effect developed nevertheless.

The PEM effect was found to grow with increasing exposure time, and it dissipated completely in 5 min. These findings will be useful in assessing the influence of the effect in other experiments involving pursuit eye movements that employ prolonged exposure.

Table 1
Mean Tilt Estimates After Exposure Periods of Various Durations

Exposure Period (in Minutes)	Mean Tilt Estimate (in Degrees)
2.5	45.3
5.0	46.7
10.0	46.1
20.0	48.3

Note—Average of four preexposure means = 43.3 deg.

REFERENCES

Coren, S., Bradley, D. R., Hoenig, P., & Girgus, J. S. The effect of smooth tracking and saccadic eye movements on the perception of size: The shrinking circle illusion. *Vision Research*, 1975, **15**, 49-55.

Robinson, D. A. The mechanism of human smooth pursuit eye movement. *Journal of Physiology*, 1965, **180**, 569-591.

Wallach, H., & Bacon, J. Two kinds of adaptation in the constancy of visual direction and their different effects on the perception of shape and visual direction. *Perception & Psychophysics*, 1977, **21**, 227-242.

Wallach, H., Bacon, J., & Schulman, P. Adaptation in motion perception: Alteration of induced motion. *Perception & Psychophysics*, 1978, **24**, 509-514.

NOTES

1. For a discussion of the conditions of stimulation that cause motion perception see Wallach, Bacon, and Schulman (1978).

2. Object-relative displacement will here tend to cause nonveridical perceived motion because the background motion will cause induced motion of the target. This induced motion will combine with the target's own motion, and the resultant will be the target's object-relative displacement. This is one way of conceiving this stimulus condition. We prefer the way used subsequently in our text: The background is taken as the framework in relation to which the target is being displaced, and that displacement is the target's object-relative displacement. It happens to result here from two objective motions, that of the target and the motion of the background.

3. Such a cue conflict is always present when induced motion operates (Wallach et al., 1978). When the target that is seen against a moving background is objectively stationary, it is given as stationary by the combination of the subject-relative conditions of stimulation when, at the same time, it is given as moving by object-relative displacement.

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