Perception & Psychophysics
1973, Vol. 13, No. 2, 164-168

Movement and illumination factors in adaptation to prismatic viewing*

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While wearing laterally displacing prisms, Ss were required to align a spot of light to the phenomenal straightahead. These measurements were obtained at the beginning and at the end of an exposure to prismatic displacement. In addition, Ss either actively controlled movement of the spot of light, or movement was manipulated by E under the direction of the S. Aftereffects were determined by having S position the spot of light with normal vision at the beginning of the experiment and after each measurement obtained under prism viewing. Ss in the darkened room condition who were required to align the spot of light actively showed a significant aftereffect in the direction of prismatic displacement both at the beginning and at the end of the exposure period. No difference in the degree of adaptation was found between those measurements at the beginning and at the end of the exposure period. No significant aftereffects were found when the room was illuminated during prism exposure or when E controlled movement of the light source.

Rock, Goldberg, and Mack (1966) had Ss wear 20-diopter lateral displacing prisms and position a spot of light to the apparent straightahead. In a dark room, the apparent straightahead deviated from veridicality by approximately the amount of prismatic displacement. However, when the room was illuminated, the Ss now positioned the target several degrees closer to the true straightahead. This immediate "correction effect" seemed to be dependent only on the Ss' ability to observe their three-dimensional surroundings. In addition, Rock et al found that stationary Ss, viewing their environment for an additional 10 min after the correction effect was measured, showed a sizable aftereffect in the direction of the prismatic displacement when the prisms were removed. The measurement of this aftereffect was assessed as the difference in initial and final setting of the spot of light to the phenomenal straightahead under zero prismatic displacement in the dark. The intervening exposure condition under illumination between initial and final setting of the spot of light involved 20-diopter prismatic displacement.

Melamed and Wallace (1971) found significant correction effects for prism displacements ranging from 10 to 30 diopters. However, no relationship was found between this correction effect and visual adaptation of the phenomenal straightahead following a 15-min exposure in which stationary Ss viewed the environment as in the Rock et al procedure. The size of the correction effect (3.8 deg) for the 20-diopter condition was comparable to that obtained by Rock et al. A methodological difference in the procedures for aligning the spot of light to the phenomenal straightahead in the two studies may have influenced the discrepant results. In Rock et al's study, the S controlled movement of a projector which was used to align the spot of light to the phenomenal straightahead. Melamed and Wallace had the E move the projector and align the spot of light to the phenomenal straightahead under the S's direction. It is possible that in the former condition, the spot of light becomes an extension of the S's hand that is moving the projector and, thus, measurements under prismatic viewing become a situation of viewed active movement, in which case an aftereffect would be expected (Held & Schlank, 1959). In the study by Rock et al, two measures were taken of the alignment of the spot of light while viewing through prisms. One measure in the dark and one in the illuminated room were taken to calculate the correction effect. The total time required for obtaining both measures of straightahead was approximately 5 min in the Melamed and Wallace experiment. Since it has been shown that adaptation to prismatic displacement can occur in as little time as 3 min under active movement (Held & Schlank, 1959), it is possible that adaptation to the phenomenal straightahead in Rock et al's study could have occurred during spot alignment under prismatic displacement in the dark and/or under illumination, as a function of active movement by the S. If this is the case, the correction effect, per se, would be irrelevant to subsequent adaptation. In addition, the exposure condition following manipulation of the correction effect may also have had little influence in the establishment of adaptation to the phenomenal straightahead.

Since Melamed and Wallace did not obtain adaptation following a manipulation of the correction effect paradigm and using an exposure condition comparable to that of Rock et al, the correction effect will not be

*This research was supported by Grant MH-20504 from the National Institute of Mental Health to the second author.

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dealt with in the present study. The focus of the present study, instead, is on the procedures used in locating the spot of light that preceded the exposure period in the two previously mentioned studies.

Following a baseline measurement under normal vision in the present study, Ss, while wearing prisms, were required either to actively align the spot of light to the apparent straightahead or to direct the E in positioning the light. Immediately after this task, another measure of spot placement was taken under normal vision. In addition, these procedures were followed either in a darkened room or under illumination. These two conditions were derived from the correction effect paradigm where a measure of straightahead is taken under illumination and in the dark. It was predicted that Ss actively controlling the placement of the spot of light would show significant aftereffects. No differential prediction was made concerning the illumination variable. If adaptation is produced in the active preexposure manipulations under illumination and/or under darkness, this resultant adaptation must be maintained during an exposure period. This assumption stems from the fact that Rock et al obtained significant aftereffects even though they were measured after the exposure condition, and it has been shown by Melamed and Wallace that the exposure condition, per se, is not sufficient to produce adaptation.

Immediately following the preexposure measurements in Experiment I of the present study, a 10-min exposure period occurred, in which the movement and illumination conditions were maintained as before. Aftereffects were again measured at the conclusion of this period. The purpose of this procedure was twofold: (1) Given that adaptation occurs during the brief time it takes to position the spot of light in the preexposure condition, it would be interesting to see if it is enhanced by extended viewing periods. Visual-motor adaptation, using the method of Held, shows a considerable increase during the first 10 min of exposure period (Efstathiou, 1969). Rock et al argue that the two forms of adaptation are related; this would lead to the prediction of an enhancement in adaptation to the visual direction of "straight ahead" with extended exposure to optical displacement. (2) If adaptation does not occur during the preexposure condition, it is still necessary to see if extended exposure to the experimental conditions will produce it.

Furthermore, if the spot of light in the present study is viewed as an extension of the S's arm, it would be imperative for a S to sense some necessary relationship between the position of the projected spot of light and the position of the arm guiding the projector. Experiment II provides a test for this possible relationship.

In addition, Experiment II provides a test in the dark for aftereffects occurring as the result of the light preexposure condition in which S positions the spot of light under prismatic viewing. This test was performed for both an active movement group and under S-directed movement where S tells E where to align the spot of light. Thus, alignment of a spot of light under normal vision was performed in the dark before and after an exposure to prismatic displacement in the light. These conditions were a response to the argument that tests for aftereffects performed with normal vision in an illuminated room may be invalid because S can merely position the stimulus using visible external referants. It was felt that these procedures would provide converging evidence on the existence of these aftereffects.

EXPERIMENT I

Method

Subjects

Forty undergraduates from the introductory psychology sections served as Ss. Only Ss who did not wear corrective glasses were selected.

Apparatus

The Ss were seated at a small wooden table, 60.8 x 121.6 cm, with their heads securely positioned on a combination head- and chinrest. Ss wore Risley rotating prisms attached to the front surface of welder's goggles. To the right of the S, on the table, was a partition, 91.2 cm high and attached to the table, preventing S from observing an Anscomatic II slide projector. The projector was the source of illumination for a 1-deg circular light projected on the far wall facing the S, 3.7 m distant. The projector was placed on a wooden swivel container, allowing either the E or the S to move the projector controlling the source of light. For half the Ss, a wooden handle was attached to the swivel container, allowing the S to control movement of the light source. In addition, a metal pointer was attached to the wooden container which, when moved, registered the number of degrees of displacement on a protractor. During all conditions in this experiment, the S's hand was out of sight, even when the S controlled movements. His hand was located far below eye level of the visual field.

Design

A 2 x 2 factorial design was used in which one factor concerned the manner of movement used in positioning the spot of light to the apparent straightahead. Either active movement of the S (active) or movement directed by the S but performed by the E (S-directed) was employed. The second factor involved the room being either illuminated (illuminated) or completely dark (darkened), except for illumination of the light stimulus, during all experimental procedures. Ten Ss were assigned randomly to each of the four groups. Only base left prisms were used in this study, since Melamed and Wallace found no difference in the size of the correction effect or any significant adaptation as a function of direction of prism displacement.

Procedure

All Ss were led into the experimental room blindfolded and seated in a chair. Their heads were then positioned in a combination head- and chinrest. The blindfold was then removed and replaced with welder's goggles on whose front surface Risley prisms were attached binocularly. Using the method of adjustment, Ss were asked to align a 1-deg spot of light to the

Table 1
Mean Aftereffects (Degrees) in the Direction of Prismatic Displacement as a Function of Preexposure 2 Manipulation with Either Active or S-Directed Movement and Room Illumination Condition (Illuminated or Darkened)

		Room Illumination Condition			
		Illuminated		Darkened	
		Mean	SD	Mean	SD
Type of Movement	Active	1.2	.49	2.8*	.73
	S-Directed	0.4	.67	0.7	.51

Note—Analyses were by two-tailed t tests for correlated measures.
$*p < .001$

Table 2
Mean Aftereffects (Degrees) in the Direction of Prismatic Displacement as a Function of Exposure Manipulation with Either Active or S-Directed Movement and Room Illumination Condition (Illuminated or Darkened)

		Room Illumination Condition			
		Illuminated		Darkened	
		Mean	SD	Mean	SD
Type of Movement	Active	0.1	.19	2.6*	.53
	S-Directed	0.2	.24	−0.7	.39

Note—Analyses were by two-tailed t tests for correlated measures.
$*p < .001$

phenomenal straightahead four times, starting in a random order from the right or left of the visual field, in each of the following five conditions: *Preexposure 1*—A baseline estimate of straightahead was established in a preexposure alignment by the Ss under zero prismatic displacement. *Preexposure 2*—Under 20-diopter prismatic displacement, Ss then aligned the spot of light to the phenomenal straightahead. *Preexposure 3*—Prisms were then again set to zero prismatic displacement and a measure of straightahead was again taken. *Exposure*—Ss were then exposed to 20-diopter prismatic displacement for a period of 10 min, during which the spot of light was moved continuously back and forth across the visual field. The movement of the spot of light was either actively controlled and observed by S or controlled by E and passively observed by S. A metronome set to beat every 5 sec was used to standardize movement. *Postexposure*—The final assessment of location of the phenomenal straightahead required setting the prisms back to zero displacement and asking Ss to align the spot of light to the phenomenal straightahead once again. In all five conditions, the spot of light was moved actively by half the Ss, whereas for the other half movement was controlled by E. In the latter case, when adjustments to the apparent straightahead were required, Ss directed the E's movements. Half the active-movement Ss and half of the S-directed-movement Ss received all conditions with room illumination, whereas the remaining Ss received all conditions with the room dark.

Results

Three analyses of variance were performed on the data of this experiment. All analyses involved a 2 x 2 factorial design in which the factors were movement condition (active or S-directed) and illumination condition (illuminated or darkened). In the first analysis, the dependent measure was the placement of the spot of light to the phenomenal straightahead during the Preexposure 1 measurement, in which there was no prismatic displacement. No significant difference was found between active movement and S-directed movement in alignment of the light stimulus [$F(1,36) = .001$]. Similarly, no significant difference was found between alignment of the spot of light under illumination or in the dark [$F(1,36) = 2.06$]. The interaction of Movement by Illumination was also found not to be significant [$F(1,36) = .007$].

The second analysis concerned the aftereffects produced during the second preexposure procedure, in which S positioned the spot as viewed under 20-diopter prismatic displacement. The aftereffect was obtained as the difference in the placement of the spot of light between the Preexposure 1 and Preexposure 3 determinations of the apparent straightahead; both of these measurements involved normal vision. The aftereffect was considered positive when the placement of the spot of light was shifted in Preexposure 3 towards the direction of prismatic displacement in Preexposure 2. This is the direction of the aftereffects predicted by Rock et al. A significant difference was found between the aftereffects produced by the active and S-directed-movement conditions [$F(1,36) = 6.74$, $p < .01$]. A mean aftereffect of 2.1 deg was found for the active-movement condition as compared to 6 deg for S-directed movement. The difference between illumination conditions was not significant [$F(1,36) = 2.91$]. Although the interaction of Movement by Illumination was not significant [$F(1,36) = 1.33$], Newman-Keuls analysis indicated that the active-movement/dark-illumination group provided significantly greater aftereffects, at the 5% level, than that of each of the other three groups. No other differences were significant. The average aftereffects for the four experimental groups are presented in Table 1. These means were analyzed using a two-tailed t test for dependent measures. The only significant aftereffect was that for active movement/dark illumination (2.8 deg) [$t(9) = 8.95$, $p < .001$]. S-directed movement in the dark produced an aftereffect of .7 deg. For active and S-directed movement in the illuminated experimental room, the mean aftereffects were 1.2 and .4 deg, respectively.

The third analysis concerned the aftereffects produced by the 10-min exposure period. In this case, aftereffects were measured as the difference between Preexposure 1 and postexposure measures of the phenomenal straightahead, both determined under normal vision. These aftereffects were considered positive, i.e., in the expected direction, when the postexposure measures were biased towards the direction of prismatic displacement used in the exposure condition. As in the previous analysis, a significant difference was found in the size of the aftereffects for active movement (1.4 deg) and S-directed movement (−.2 deg) [$F(1,36) = 6.30$, $p < .02$]. Lighting condition was not found to be significant [F(1,36) = 1.44]. The interaction of Movement Type by Lighting Condition was significant [F(1,36) = 7.37, p < .01]. A Newman-Keuls analysis of the group means involved in this interaction showed that the source of the interaction was that the aftereffect for the active-movement/dark-illumination group was significantly larger, at the 1% level, than that of each of the remaining groups. No other differences were significant. The group means along with the t-test analysis are presented in Table 2. Again, the only significant aftereffect is that for the active-movement/dark-illumination group (2.6 deg) [t(9) = 8.35, p < .001]. S-directed movement in the dark produced an average aftereffect of −.7 deg, whereas active and S-directed movement produced aftereffects of .1 and .2 deg, respectively, under room illumination.

No significant difference was found between adaptation produced by the Preexposure 2 procedure and that produced by the exposure procedure for any of the Movement Type by Lighting Condition groups [F(1,36) < 1.00].

EXPERIMENT II

Method

Subjects

Twenty undergraduates from the introductory psychology sections served as Ss. Only Ss who did not wear corrective glasses were selected.

Apparatus

The equipment used was the same as in Experiment I.

Design

The manner of movement used in positioning the spot of light to the apparent straightahead was the primary factor in this design. Either active movement of the S (active) or movement directed by the S but performed by E (S-directed) was employed. Both types of movement took place in the dark for all spot positioning except for an intervening measure of straightahead taken under illumination with prismatic displacement. Ten Ss were assigned randomly to each of the two groups.

Procedure

The procedure for assessing accuracy in alignment of the spot of light to the phenomenal straightahead was essentially the same as in Experiment I. The exact procedure for this study was as follows: *Condition 1*–A baseline estimate of straightahead was established by asking Ss to align the spot of light under zero prismatic displacement in the dark. *Condition 2*–Under 20-diopter prismatic displacement under illumination, Ss then aligned the spot of light to the phenomenal straightahead. *Condition 3*–Prisms were then again set to zero prismatic displacement with the room darkened, and a measure of straightahead was again taken. *Condition 4*–The final assessment of location of the phenomenal straightahead required that the illumination source for projecting the spot of light be turned off. Under room illumination and under zero prismatic displacement, the S was required to align the projector itself, without a spot of light being projected, so that it pointed to the phenomenal straightahead. In the first three conditions, the spot of light was moved actively by half the Ss, whereas for the other half, movement was controlled by E but directed verbally by S. In Condition 4, all Ss actively aligned the projector itself to the phenomenal straightahead with the aid of a handle attached to the projector.

Results

Three one-way analyses of variance were performed on the data of Experiment II. All analyses involved a comparison of active vs S-directed movement in alignment of a spot of light to the phenomenal straightahead. In the first analysis, the dependent measure was the placement of the spot of light to the phenomenal straightahead during Condition 1 under normal vision. No significant difference was found between active movement and S-directed movement in alignment of the light stimulus [F(1,18) = .003].

The second analysis concerned the produced aftereffects which were obtained as the difference between Condition 1 and Condition 2 in placement of the spot of light under normal vision. The aftereffect was considered positive when the placement of the spot of light was shifted in Condition 3 towards the direction of prismatic displacement in Condition 2. A significant difference was not found between the aftereffects produced by the active and S-directed movement conditions [F(1,18) = 2.92]. In addition, adaptation as measured by a two-tailed t test for correlated measures found the aftereffect produced under active movement (.2 deg) and the aftereffect produced under S-directed movement (.5 deg) not to be significant from zero.

The third analysis was concerned with the difference in the accuracy of Ss in aligning the projector itself to the phenomenal straightahead (Condition 4) with alignment of the projected spot of light to the phenomenal straightahead (Condition 1). No significant difference was found between the accuracy of alignment of the spot of light in Condition 1 and projector alignment in Condition 4 [F(1,18) = 2.13].

DISCUSSION

A significant aftereffect in the direction of prismatic displacement was found to result from S aligning a spot of light to the phenomenal straightahead in the dark under active movement in the Preexposure 2 condition of Experiment I. The aftereffect did not increase in size following the 10-min exposure condition. This finding supports the argument that adaptation of the phenomenal straightahead occurred during the measurement of the correction effect in Rock et al (1966). Part of their procedure also involved active adjustment of the prismatically displaced light stimulus in a darkened experimental room. Although Rock et al propose that the adaptation results from a subsequent exposure condition in which S passively stares ahead in an illuminated room, this is contradicted by two sources of evidence. First, significant aftereffects resulted only from *active* movement in a *darkened* experimental room during all manipulations in the present study. This is seen clearly in a comparison of the results of Experiments I and II. In addition, Melamed and Wallace (1971) did not find that the Rock et al exposure condition led to aftereffects in visual direction. That study did not allow for active manipulations of the light spot by the S in the measurement of the correction effect. Thus, the exposure condition of the Rock et al study most likely served to maintain adaptation.

The essential features of the adaptation that occurred in the present study are that it depended upon (1) a darkened background in which only the light stimulus was visible, (2) active movement of the light stimulus by the S, and (3) the fact that the adaptation had a very fast "rise time." The 10-min exposure condition involving active movement in the dark did not enhance the aftereffect found after Preexposure 2 in Experiment I. This latter finding may have been due to the fact that S was not specifically adjusting the stimulus to the apparent straightahead during the exposure condition but only moving it in a continuous lateral movement. If this, in fact, was the reason, the adaptation in visual direction obtained from Preexposure 2 is a limited unique type of adaptation, in the sense that change can occur only in relationship to one particular mode of orienting oneself.

The fact that aftereffects of prism viewing were obtained only with active movement when the visual field was dark may relate to how the S performs the task of aligning the spot of light under the two illumination conditions. In the darkened experimental room, the prismatically displaced spot of light is the only available stimulus that the S can relate to his own egocentric localization. It would clearly serve the purpose of the viewed arm in the Held paradigm (Held & Schlank, 1959). On the other hand, under room illumination, there are a multiplicity of external cues for indicating spatial orientation that may be attended to. The importance of active movement in the adaptation to prismatic viewing found in the present study is consistent with the interpretation that the spot of light is viewed as an extension of the S's arm in the process of adaptation, i.e., that the paradigm resembles that found effective by Held and his coworkers where S merely observes his own active movement of the arm upon a homogeneous visual background. This interpretation is further supported by the results of Experiment II, where alignment of the spot of light to the phenomenal straightahead did not significantly differ from alignment of the projector itself to the phenomenal straightahead. Thus, it can be concluded that a S senses a relationship between the position of his arm guiding the projector and the position of the projected spot of light.

The specific role of active movement is not investigated in the present study. One further note on the role of active movement and its relationship to the Held paradigm concerns Rock et al's finding that the size of the aftereffect in the apparent straightahead decreases sharply *during* the actual measurement of the aftereffect. Thus, if one compared the latter half of the measurements of the straightahead obtained during the postexposure condition to those obtained at the start of the condition, there is a large decrease in the size of the aftereffect. This is expected if the measurement situation (normal vision, active movement of the light stimulus, darkened room) is viewed as a Held paradigm. The S is readapting from a 20-diopter to a 0-diopter visual field.

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(Received for publication April 26, 1972; revision received August 3, 1972.)