Prism adaptation: The "target-pointing effect" as a function of exposure trials*

ROBERT B. WELCH

University of Kansas, Lawrence, Kansas 66044

The amount by which target pointing enhances prism adaptation (the "target-pointing effect") was examined as a function of exposure trials. Each S served in three conditions—target-pointing, no-target, and control—wearing 20-diopter prism goggles in the first two. The S was measured prior to the exposure period on target-pointing accuracy with normal vision but with no visual feedback regarding his performance. Similar measures were taken after the 5th, 10th, 15th, 25th, 35th, 55th, and 95th exposure trials and after each of two consecutive 5-min postexposure periods in the dark. The two experimental conditions led to sharply rising and negatively accelerated adaptation ("negative aftereffect") curves, the asymptotes of which differed markedly, in favor of the target-pointing condition. This difference in asymptotes indicates that the target-pointing effect is not limited to the early portion of the exposure period but, instead, is a relatively permanent phenomenon. There was no decline in adaptation during the postexposure period.

According to Held and his collaborators (e.g., Held & Freedman, 1963), motoric adaptation to prism-displaced vision requires active visuomotor involvement. Recent evidence, however, indicates that if S's active movements include pointing at targets, with the resulting error-corrective feedback, prism adaptation is greatly augmented (Coren, 1966; Freedman, 1968; Welch, 1969; Welch & Rhoades, 1969). This phenomenon will be referred to as the "target-pointing effect." Because in the latter studies adaptation was measured only once—after a fixed number of prism-exposure trials—the longevity of the target-pointing effect is uncertain. Thus, it is possible that the difference in adaptation between target-pointing and no-target conditions eventually diminishes to zero as a function of exposure trials. The primary aim of the present study was to examine this possibility. To the writer's knowledge, only one previous study (Goldberg & Taub, 1968) has compared the effects of different kinds of prism-exposure activity upon the postexposure decline of motoric adaptation. Therefore, a second goal was to examine the decay of adaptation for target-pointing and no-target conditions during a postexposure period in the dark.

METHOD

Subjects

Twelve students of both sexes from an introductory psychology course at the University of Kansas served in the experiment as partial fulfillment of the course requirements. All were naive as to

the nature of the investigation and had normal or near-normal vision.

Apparatus and Procedure

An 11-deg leftward displacement of S's visual field was effected by welder's safety goggles containing a 20-diopter wedge prism in front of each eyepiece. The major apparatus was based on a device first used by Wooster (1923) and a close approximation of it has been illustrated elsewhere (Welch & Rhoades, 1969). Basically, it consisted of a horizontal "occluding board," supported 12 in. above a table. On the near edge of the board was affixed a dental impression bite plate and on the far edge, 20¼ in. away, a vertical 7¼ x 3/16 in. target hung from a tightly stretched rubber cord, located directly above and parallel to the edge of the board.

During the exposure and response-measurement periods, S inserted his teeth into the bite plate, thus stabilizing the position of his head, and faced E across the occluding board. At the outset a measure was taken of S's target-pointing ability without goggles. He pointed by reaching with his right hand under the board and curling his index finger around the far edge at the apparent location of the target. He was precluded from any visual feedback regarding his target-pointing accuracy during these preexposure trials by means of a 2-in.-high wooden barrier, which was placed adjacent and parallel to the far edge of the board, thus blocking S's view of his finger when it curled around the edge. The S pointed eight times at the target, located in the center of his visual field. These trials were preceded by several practice attempts (without feedback). If S tended to make a large error (over 3 cm) during the practice trials he was allowed to point a number of times with feedback

(i.e., the barrier was removed) until his no-feedback localizations were consistently within 2 cm of the target. All target pointing (except during part of the practice period) was done in the dark, the target being visible as a result of a strip of luminous tape running its length. Each pointing response began with the right hand in a resting position at the near edge of the table, to S's right. The S wore a luminous rubber finger with a thin wire attached to its palmar surface. The wire left a narrow, vertical mark in a strip of clay at the far edge of the board whenever S pointed at the target. After each pointing response, E lowered a sliding door, located 7 in. directly in front of S's eyes, turned on the lights, and measured the accuracy of S's response by comparing the mark with a ruler running parallel to the strip of clay. The S kept his eyes shut while his response was being recorded and left his mouth on the bite plate throughout the entire preexposure period.

After the preexposure target-pointing responses had been made, S was given practice in reaching under the board in time to the recorded beat of a metronome, set for one beat every 2 sec. The wooden barrier was removed and S practiced making a smooth in-and-out arm movement such that the finger appeared at the far edge of the occluding board on every other beat and in a position to his right, at the near edge of the board, on the intervening beats. He kept his hand in contact with the underside of the board at all times during the arm movement. After S was proficient in making this response, he was told that he would be wearing goggles that displaced his vision to the left (except in the control condition, in which he was correctly informed that the goggles did not distort his vision). Placement of the goggles on S's head was followed by a series of trials to the beat of the metronome. Thus, during this part of the experiment—the exposure period—S was allowed to see his luminous index finger when it curled around the edge of the board in the otherwise dark testing room. However, no attempt was made to record where S had pointed. Consequently, the lights remained off during and between all exposure trials, and the sliding door was left up. After a specified number of exposure trials, the goggles were removed and S was required to make four target-pointing responses without any feedback. These responses were recorded and in all other ways the procedure was identical to that used in the preexposure period. A four-trial series of these measurements occurred after the 5th, 10th, 15th, 25th, 35th, 55th, and 95th exposure trials. The S kept his eyes closed during the short interval of time between removal of the prism goggles and the first

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target-pointing measurement. After the last of these series of measurements had occurred, S was asked to close his eyes and to keep them shut while he sat quietly for 5 min in the dark. He was then given another four trials on no-feedback target pointing without the goggles. A second 5-min period in the dark was followed by the final measure of target pointing. Because it took approximately 2 min for each of the three series of measurements that followed the last exposure trial, the total time from the end of exposure period to the final measurement of target-pointing accuracy was 16 min.

The dependent variable was the difference between S's average preexposure target-pointing localization and the average localization after a period of exposure (or of sitting in the dark). This shift in pointing, when in the direction compensatory to the prism displacement, is called the "negative aftereffect" (NA).

Each S was used as his own control in three conditions separated in time by at least 1 week. The conditions were labeled target-pointing, no-target, and control, and their order was completely counterbalanced across Ss. In the target-pointing condition S wore prism goggles and pointed at the target, the position of which was changed by E from trial to trial, in a fixed irregular order. The S was instructed to deliberately and completely correct his pointing after his first trial, but not by moving the visible finger sideways. Rather, he was to keep it stationary, while noting his error, and on the following trial attempt to bring the finger up accurately. In the no-target condition S wore the prism goggles and was instructed to curl his finger around the far edge of the board, looking at it for the short period of time (approximately 1 sec) that it was visible. From trial to trial he was to "randomly" vary the placement of his finger, being sure to cover the entire range of possible positions. Thus, an attempt was made to keep the two experimental conditions alike regarding the variety of positions in which the finger was viewed. Unfortunately, a difference remained, due to the fact that in the no-target condition S was free to choose his "random positions," while these were determined for him in the target-pointing condition by the placement of the target. The result of allowing S to choose his own finger placements in the no-target condition was that he used a greater diversity of positions (by the end of the exposure period) than was available in the target-pointing condition. In a study by Welch (1967) it was shown that the greater the variety of positions in which S's finger is viewed through the prism goggles, the

Fig. 1. Negative aftereffect (centimeters) as a function of exposure trials.

greater the adaptation. Hence, although confounding existed in the present experiment, it was pitted against the predicted difference in adaptation between the two experimental conditions.

RESULTS

Figure 1 reveals the results of the exposure period. In order to present complete adaptation curves, the assumption was made that no change in target-pointing accuracy would have occurred if a test had been made after zero exposure trials. Using Ss as one factor, a three-way analysis of variance, with repeated measures on two factors, was carried out on the NA scores (in centimeters). Because even a very small "F" may prove statistically significant when there is a relatively large number of repeated measures, the most conservative degrees of freedom were used in the test, namely 1 and 11. Significant (.05) effects were found for conditions ($F = 56.48$), trials ($F = 22.16$), and the Conditions by Trials interaction ($F = 6.60$). Examination of Fig. 1 suggests that the interaction was due to the essentially flat curve of the control condition. However, it might also be attributable, in part, to a differential rate of adaptation for the two experimental conditions. In order to evaluate this latter possibility, the analysis of variance was repeated with the control condition data omitted. The interaction failed to reach significance [$F(6,66) = 2.06$, $p > .05$], revealing that the adaptation curves of the two

experimental conditions were, in effect, parallel. A series of Scheffé tests indicated that at each measurement point the mean adaptation score of each condition differed significantly (.05) from that of the other two conditions.

The decay-of-adaptation curves are seen in Fig. 2. The time indicated on the abscissa does not include the 2 min taken each time the level of adaptation was measured. A three-way analysis of variance of the type used on the adaptation data revealed that the only significant (.05) effect was for conditions [$F(1,11) = 41.05$]. Scheffé tests indicated that the scores of all conditions differed significantly (.05) from one another at each measurement point.

DISCUSSION

An interesting result of the experiment was the very rapid rate at which adaptation took place. The NA curve for each of the two experimental conditions reached asymptote after about 35 trials. This represents approximately 35 sec of prism exposure, as S's finger was visible for about 1 sec on each trial. The finding of a sharply rising, negatively accelerated adaptation (NA) curve agrees with the results of previous studies of visuomotor prism adaptation (Wertheimer & Arena, 1959; Hay & Pick, 1966; Held, Efstathiou, & Greene, 1966; Greene, 1967; Rekosh & Freedman, 1967; Efstathiou, 1969). More important, however, is the fact that the adaptation curves of the two experimental conditions reached plateaus that were at

Fig. 2. Negative aftereffect (centimeters) as a function of postexposure minutes (not including time taken to measure negative aftereffect).

markedly different levels. A conservative estimate of asymptote for the target-pointing condition is 6.5 cm; for the no-target condition it is 4.0 cm. Because there is no indication that the curves would ever join together, one may reject the hypothesis that the target-pointing effect is limited to the early portion of the prism-exposure period.

In order to calculate the percent of adaptation achieved in the experimental conditions, it is necessary to know how much the prism goggles displace the image of S's finger when viewed at the far edge of the occluding board. An empirical test of the magnitude of prism displacement was carried out with 20 new Ss. Each S sat in the dark testing room with his head fixed on the bite plate. He turned a motor switch with his left hand, which caused the luminous target to move from the far left or far right of his visual field toward the center. His task was to terminate the movement of the target when it appeared to be straight ahead of his nose. He did this 10 times with prism goggles on and 10 times with clear-glass goggles, the order of these two conditions being counterbalanced across Ss. At no time was S allowed any feedback concerning his accuracy. It was assumed that the difference between the mean setting with prism displacement and the mean setting without represented the amount by which the goggles displaced S's vision. The difference was 7.6 cm, and it was concluded that this number represents the largest possible NA that could have occurred in the main experiment. Based on this figure, the curve for the target-pointing

condition reached asymptote at 86% of total adaptation, while the corresponding score for the no-target condition was 53%. Thus, in neither condition was full compensation attained, although Ss in the target-pointing condition came close to this maximum.

In a recent study by Efstathiou (1969), visuomotor prism adaptation was induced by means of an exposure condition in the Held-Gottlieb (1958) apparatus, which was especially constructed to preclude error-corrective feedback. The investigator found that adaptation for her Ss reached its asymptote at 47% and noted that this contrasts markedly with the results of a study by Wertheimer and Arena (1959). The latter investigators reported an adaptation curve that reached 60% after 20 sec of prism exposure (the longest period used) and had not yet levelled off. As Efstathiou (1969) points out, one of the differences between her study and that of Wertheimer and Arena (1959) is that the latter included target-pointing experience. The present study appears to confirm her suggestion that the presence or absence of error-corrective feedback is the basis for the marked difference in levels of adaptation found in the two studies.

The results of the postexposure period were surprising. Adaptation failed to reveal any decay for either experimental condition. This finding contradicts those of Hamilton and Bossom (1964), Goldberg, Taub, and Berman (1967), and Goldberg and Taub (1968), all of whom found complete or nearly complete disappearance of adaptation after postexposure periods in

the dark ranging in length from 15 min to about 1 h. Further investigation will be necessary to explain why adaptation apparently remained unchanged during the postexposure period in the present experimental situation.

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