Adaptation to displaced vision: Variations on the "prismatic-shaping" technique*

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Adaptation to displaced vision was measured, using three variations on Howard's (1968) "prismatic shaping technique." Over a series of 40 trials, a lateral displacement of 11.3 deg was introduced either gradually or suddenly. Both the amount of adaptation (negative aftereffect) and the accuracy of target localization at the completion of 40 trials were found to be directly related to the "suddenness" with which the displacement was introduced.

Research on adaptation to displaced visual input has for the most part used a fairly stereotyped procedure. It involves measurement of the S's ability for spatial localization before and after exposure to an optical device that displaces the visual input by a specified amount. The optical device (typically a 20-diopter wedge prism, inducing 11.3 deg of lateral displacement) is suddenly introduced following a number of preexposure trials in which the S is required to localize a target by pointing to or touching it. This sudden introduction of the distorting device creates a substantial error in spatial localization; however, the S readily corrects this error with practice. It is difficult to determine exactly what the S is doing when adapting to this sudden change, since a sizable displacement will no doubt alert him to the fact that something is different about his visual field. This raises the possibility of the S's compensating in a "cognitive" manner (Webster, 1969) and making corrective adjustments for the distortion without undergoing any fundamental perceptual, sensory-motor, or motor change.

A method recently devised to overcome this problem is the "prismatic shaping" technique developed by Howard (1968), which involves the gradual introduction of a sizable displacement of the visual input over a series of trials. The S points to a target while viewing it through a variable wedge prism set at 0 diopters (no displacement). Over a series of trials the strength of the prism is gradually changed so that the S is unaware of the change. As the prism strength is increased, the S shifts his pointing response in such a way that he seldom makes any substantial error, even up to a lateral displacement of 15 deg.

This technique has some similarities to the "pacing" procedure used in discrimination learning experiments (e.g., Lawrence, 1952). That is, a difficult task is introduced gradually in such a way that the

S makes relatively few errors in the discrimination, even though the task eventually becomes very difficult. The result of such training is more accurate performance on a difficult task following its gradual introduction than following its introduction at the beginning of training.

Schrier, Stollnitz, and Green (1963) have also employed a similar method for training monkeys on a difficult discrimination. They increased the distance between the discriminanda and the manipulanda in a modified Wisconsin General Test Apparatus after two correct responses at a given separation. This "titration" technique resulted in correct performance of difficult discriminations more rapidly than did a method involving many more trials in which S was required to reach a specified performance criterion before proceeding to the next separation level.

The only direct comparison between Howard's shaping technique and other methods has been made by Freedman (1968a), who measured adaptation to a 20-diopter wedge prism using the procedures of Harris (1963), Held and Gottlieb (1958), and Howard (1968). Harris measured accuracy of target localization before and after S viewed his hand through a wedge prism as he pointed to the target. Held and Gottlieb measured hand-eye coordination before and after prism exposure by having S mark the location of a target with the unseen hand. Exposure to displacement involved S's viewing his hand as he moved it back and forth across his visual field (with no target pointing). During the prism-exposure phase both of these procedures introduced the displacement immediately, whereas Howard's method involved a gradual introduction of the displacement. Freedman (1968a) found that Howard's technique produces about the same amount of adaptation as does the technique of Harris, but somewhat more than the technique used by Held and Gottlieb.

If this adaptation phenomenon, a type

of perceptual learning, is influenced by the gradual introduction of a difficult task (locating a target displaced by 11.3 deg) in a manner similar to the discrimination experiments mentioned above, then it would be expected that the "prismatic shaping" technique would lead to greater adaptation than would other methods. However, Harris's method was as effective as that of Howard, and the smaller adaptation produced by the Held and Gottlieb technique may be attributable to the lack of target-pointing during prism exposure. Welch (1969) has reported that adaptation (measured in terms of the negative aftereffect) varies directly with the specificity of the target.

In order to examine this problem further, three variations of the shaping technique were employed to determine if the gradual introduction of a sizable displacement is any more effective than the sudden introduction of the displacement in producing adaptation to displaced vision.

METHOD

Subjects

The Ss were male volunteers from the Calgary Provincial Jail. All Ss were right handed. Their mean age was 22.3 years.

Apparatus and Procedure

The apparatus was a modification of that used by Goldberg and Taub (1967), and is described in detail elsewhere (Dewar, 1970). It consisted of a table under which S was required to reach to localize a target by pointing with his finger in such a way that a pointer attached to the finger was aligned directly behind the target (a vertical rod). The target was viewed with the right eye through a variable wedge prism with a circular visual field approximately 30 deg in diam. The S saw the position of the pointer only after the reaching response was completed, the method which Howard (1968) has called "terminal visual display."

The procedure, described in detail elsewhere (Dewar, 1970), involved a pre- and postexposure measure of accuracy of localization of the target. Forty trials were administered during exposure to the prism. Three groups of 10 Ss were used. One group (Group 1) had the prism gradually varied in steps of 2½ diopters with five trials at each prism setting up to a maximum of 20 diopters. Group 2 progressed in 5-diopter steps, with blocks of 10 trials at each setting up to a maximum of 20 diopters. Group 3 had two blocks of 20 trials, one at 10-diopter and one at 20-diopter prism strength. After each trial the eyepiece through which S looked was covered, and E set the target in one of five predetermined positions for the next trial. The S could not see E making the change in the prism strength. The total

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Fig. 1. Retention of the negative aftereffect following three methods of prismatic exposure. Exposure conditions: Group 1-8 blocks of 5 trials in 2½-diopter steps; Group 2-4 blocks of 10 trials in 5-diopter steps; Group 3-2 blocks of 20 trials in 10-diopter steps (1 cm = 1.27 deg).

testing time took approximately 40 min, with intertrial intervals long enough to allow E to record S's response and set the target for the next trial. The preexposure measure of localization consisted of blocks of seven trials (two trials in which S saw his response, followed by five trials in which he did not see his response) until the accuracy of localization was within 1 cm. Most Ss reached this criterion within one or two blocks of seven trials. The mean error on the last five trials of the final block of seven trials constituted the preexposure measure of localization. The postexposure measure of localization involved 12 trials of attempting to locate the target without seeing the response. These trials were given in pairs at 0, 2, 4, 6, 8, and 10 min, following prism exposure. This was done in order to measure the retention of the adaptation. Between pairs of postexposure trials, S sat quietly with a blindfold on.

RESULTS AND DISCUSSION

An analysis of variance performed on the data indicated that there was a significant "shaping technique" effect ($F = 3.55$, $df = 2/27$, $p < .05$), and a significant retention effect ($F = 4.29$, $df = 5/135$, $p < .005$). The amount of adaptation produced was directly related to the "suddenness" with which the distortion was introduced (see Fig. 2). The amount of adaptation decreased during the 10 min following prism exposure. Under none of the three experimental conditions did the reminiscence phenomenon (maximum aftereffect a few minutes, rather than immediately, after prism

exposure) reported by Goldberg, Taub, and Berman (1967) occur.

If the procedure used here is considered to be similar to the pacing procedures used in discrimination learning (Lawrence, 1952), then the results would appear to be opposite to those found using such pacing techniques. That is, the "learning" is less effective, rather than more effective, if the difficult task is gradually introduced. There may be two ways of interpreting this apparent conflict. If one takes into account the total "amount" of distortion (degree of distortion times number of exposure trials at that level of distortion) to which Ss of different groups were exposed, it is evident that the greatest overall amount of distortion was experienced by Group 3, and the least by Group 1. The third group, thus, had a greater opportunity for learning to adapt to the distortion, since the overall amount of distortion to which these Ss have been exposed was greater. Although this may be an important factor, it could account only in part for the results, since the differences between Groups 1 and 2 would not be as great as the difference between Groups 2 and 3 on this basis.

Another way of resolving the apparent conflict may be to use an alternate measure of the adaptation to displaced vision. One such measure involves the extent to which Ss corrected their errors during exposure to the prism. This was determined by calculating the mean error in localization on each of the 40 exposure trials. The means of these errors (in blocks of five trials) are shown in Fig. 2. It can be seen that Group 1 (blocks of five trials in 2½-diopter steps) shows a gradual increase in error throughout the 40 trials (from .6 cm in the first block of five trials to

2.5 cm in the final block of five trials). Group 2 showed a more gradual increase in error, while Group 3 showed a slight decrease from the first block to the last block of five trials.

An analysis of variance was carried out on the deviation during prism exposure for comparable blocks of trials (comparable in the sense that the same amount of distortion was involved on these particular trials). Group 1 was compared with Group 2 on Trials 6 to 10, 16 to 20, 26 to 30, and 36 to 40. The block of trials variable (6 to 10, 16 to 20, etc.) showed an increase in error from the second to the eighth block ($F = 13.04$, $df = 3/54$, $p < .001$). The trials within a block showed a decrease in error as expected ($F = 3.33$, $df = 4/72$, $p < .025$); however, there was no significant difference in overall error between these two groups. A similar analysis on the comparable blocks of Groups 2 and 3 (Trials 11 to 20 and 31 to 40) indicated all three main variables to be significant—"shaping technique" ($F = 8.06$, $df = 1/18$, $p < .025$), block of trials ($F = 6.56$, $df = 1/18$, $p < .025$), and trials within a block ($F = 2.98$, $df = 9/162$, $p < .005$). This indicates that the two groups in which distortion was introduced more gradually showed about the same amount of overall error during prism exposure. However, Group 3 showed somewhat greater compensation (smaller error) on comparable trials during exposure than did Group 2.

The findings of the present experiment demonstrate that the "prismatic shaping" technique can induce a substantial adaptation to displaced vision, an adaptation somewhat greater than that reported by many previous authors using

Fig. 2. Mean target localization error during three methods of prismatic exposure. Exposure conditions—see caption on Fig. 1.

other methods. In the comparison of Howard's shaping technique with others (Freedman, 1968a), this technique produced less than 40% of maximum adaptation after 30 trials. The present findings show an adaptation ranging from 55% (Group 1) to 84% (Group 3) of maximum adaptation (8.9 cm in this experiment) on the two trials immediately following exposure to the prism. So it is clear that the shaping technique does produce a substantial adaptation to displaced vision; however, the extent of this appears to depend on how rapidly the distortion is introduced over a series of trials.

The greater negative aftereffect produced by the most sudden introduction of prismatic distortion could be accounted for on the basis of greater target-pointing error. Welch (1969) has indicated its importance and Welch and Rhoades (1969) have reported greater negative aftereffect and greater "proprioceptive shift" under conditions which induce larger target-pointing error. Their second measure of adaptation ("proprioceptive shift") was an index of change in the felt position of the prism-exposed hand. These findings are consistent with the present results, in that both measures of adaptation (negative aftereffect and improvement in target localization during prism exposure) indicated the greatest effect under the condition where target-pointing error was largest (at least during early exposure trials). With little target-pointing error

during the gradual introduction of distortion in Group 1 there was less need to correct the pointing response and hence less information about the discrepancy between vision and touch.

The findings can be interpreted in terms of Freedman's (1968b) "discordance information" hypothesis, which proposes that the amount of adaptation is dependent upon the amount of information which S has concerning the discrepancy between vision and touch. Ss in Group 3 may have had more such information, since they showed less error in localizing the target by the end of the 40 trials of prism exposure. It is also possible, of course, that this group had more "cognitive" information (Webster, 1969) concerning the perceptual displacement than did the groups in which this displacement was gradually introduced.

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