Adaptation to prismatic distortion¹

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Abstract

This is a study of the adaptation of human Ss to long-term exposure to optical distortions produced by wedge prisms. Results indicate that the various prismatic distortions are adapted to at varying rates to varying degrees. Adaptation to the lateral displacement produced by a prism occurs rapidly and completely. Adaptation to certain shape distortions occurs slowly and to a minimal degree.

Problem

The study of adaptation to visual distortion—the kind of problem which Stratton is famous for investigating—is again receiving a great deal of attention. Recent studies by Kohler (1962) have concentrated on the study of adaptation to the chromatic aberrations of prismatic distortion. Held and his colleagues (Held & Hein, 1958; Held & Gottlieb, 1958; Held & Bossom, 1961) and Smith & Smith (1962) have been primarily concerned with the perceptual-motor aspects of short-term exposure to visual distortion.

The present report describes a series of studies of adaptation to prismatic visual distortion under conditions of relatively long-term exposure. The data pertain mostly to quantitative evaluation of the degree of adaptation and to the stimulus conditions necessary for eliciting an adaptive response. More detailed reports relevant to the specific distortions are in preparation.

Method and Procedure

These studies investigated the long-term adaptation of human Ss to the optical distortions produced by wedge prisms. Such prisms depending on their orientation produce the distortions depicted in Fig. 1. The main distortions include: (1) overall displacement of image (approximately 11° for the prisms used in the present studies), (2) curvature of vertical straight lines, (3) spectral dispersion producing chromatic fringes at vertical brightness contours, and (4) differential image displacement depending on angle of regard of eye and resulting in tilting of horizontal components of lines with head move-

ment up and down, and compression and expansion of a fixated target with head movement side to side.

The subjects in the present studies were college students ranging in age from 19 to 35 yr. They wore 20 diopter prisms mounted base right or left in spectacle frames. These were worn continuously during waking hours, for three days in one study ($N = 9$) and for 42 days in another study ($N = 8$). Peripheral vision was eliminated by means of occluders. Thus, the exposure condition consisted of manipulation of the optical channel rather than manipulation of the environment itself. Activity of the subjects was not restricted in any way.

Adaptation was assessed by a periodic battery of tests. The use of several converging methods of measurement for each distortion studied made it possible to separate perceptual adaptation from motor, verbal, or attentional adaptation. The quantitative results presented below are based on the most sensitive of these measures for each of the various distortions.

Adaptation to the overall image displacement of 11° was measured by testing the accuracy of directional localization of targets. Two indices were used: the error in kinesthetically localizing a visual target and the error in visually localizing an auditory target. To measure the error in kinesthetically localizing a visual target a test similar to one devised by Held & Gottlieb (1958) was used. The subject was asked to touch the locus of a visual target with visual feedback from his hand and knowledge of results precluded during the test. To measure the error in visually localizing an auditory target the subject was presented with a series of clicks coming from behind a meter scale. His task was to name the number from behind which the clicks were coming. These tests were ordinarily administered before and immediately after putting on the prisms as well as periodically thereafter during the prism wearing period.

To measure adaptation to the convergence of horizontal lines above and below eye level S was given the locus of one dot which was to form the lower left hand corner of a square and he was asked to move three other dots so as to complete a square. The lower right hand corner dot could only be moved in an up-down direction. Thus the width of the square was given. The ratio of the lengths of the two sides of the adjusted figure was a measure of distortion and the change of this ratio towards unity as a function of duration of exposure to prisms measured the adaptation.

To measure adaptation to all the other distortions the subject was asked to null the perceived distortion by selecting a prism strength which would just eliminate a particular kind of distortion. For example, if S had *completely* adapted to 20 diopter prisms and he was asked to find a prism power at which he detected no chromatic fringes, he should choose 20 diopters. On the other hand if he had adapted *not at all* he should choose 0 diopters. An intermediate degree of adaptation would be indicated by choice of a prism power between 0 and 20.

Results and Discussion

The results of the final tests on the 3-day and 42-day subjects are presented in Table 1 together with the nature of the most sensitive test used to evaluate adaptation for the distortion. All results have been converted to percent adaptation for ease of comparison.

For all types of prism distortion, some degree of adaptation at the perceptual level was found, as is confirmed by converging operations in addition to the measures shown in Table 1. Essentially complete adaptation is found only for kinesthetic localization of visual target. The smallest amount of adaptation is found for the differential image displacement compression and expansion.

Fig. 1. Distortion produced by base left prism.

Table 1. Per cent Adaptation of 3- and 42-Day Subjects to Various Prismatic Distortions

Distortion	Type of Measure	% Adaptation and 95% bounds	
		3 day	42 day
1. Overall Horizontal Image Displacement.			
a. Error in visual localizing an auditory target (visual-auditory)	see text	44.6 $\pm$ 23.0	not tested
b. Error in kinesthetic-localizing a visual target (visual-manual)	see text	85.8 $\pm$ 26.1	90.1 $\pm$ 19.0
2. Curvature of vertical straight lines.	Optical Channel Manipulation	11.2 $\pm$ 2.4	30.0 $\pm$ 9.2
3. Chromatic fringes at vertical contours.	Optical Channel Manipulation	16.5 $\pm$ 5.6	33.9 $\pm$ 12.1
4. Differential Image Displacement.			
a. Tilting of horizontal lines with up-down head movement.	Optical Channel Manipulation	8.4 $\pm$ 6.7	14.6 $\pm$ 6.8
b. Compression and expansion of fixated target with side to side head movement.	Optical Channel Manipulation	0.8 $\pm$ 3.8	9.8 $\pm$ 7.2
c. Convergence of horizontal lines above and below eye level.	Target Manipulation	not tested	51.5 $\pm$ 30.8

The meaning of these adaptation effects is best understood in terms of the changes in stimulus dependencies involved. The overall horizontal displacement of the retinal image involves a changed correlation between the visual and non-visual stimuli (kinesthetic or proprioceptive) produced by a given location. An adaptive change could occur in the visual or non-visual systems involved, or in the proprioceptive linkage between the receptors. Previous studies (Harris, 1963; Pick et al., 1963) indicate that adaptation to the overall image displacement during short-term *restricted* exposure to prisms is the result of some type of purely kinesthetic adaptation. The result of the visual-auditory localization test in the present investigation suggests that there is a visual directional adaptation to the image displacement under the conditions of the present study. These conditions differ from these previous studies in having both longer exposure and less restrictive conditions of activity. Some of our recent data as well as the results of Held & Bossom (1961) suggest that the different results are due to the less restrictive exposure conditions of the present studies.

The overall image curvature, as an initial distortion,

involves a change in the "average" stimulus contour exposed to the retina: the image of all targets will have a convex-left or right bias. An adaptive change could occur in the visual system's response to retinal stimulation. Similarly the spectral dispersion constitutes a bias in the spectral transitions at image contours and could be adapted to by a change in the response to such contours. A detailed analysis of the results of the present study confirm the conclusions of a previous study (Hay & Pick, 1963) that the primary stimulus dimension of which the chromatic adaption is a function is the relative luminance of the two visual fields forming a target contour.

The differential image displacement (manifest in shape changes with and without eye movements) imposes a variation on the image depending on angle of eye regard or position of the eye in the head. An adaptive change here indicates a change in the responses to both retinal and eye-positional stimulation—they must develop a counter-balancing influence on space perception.

It is apparent that the adaptation effects to the different distortions have different stimulus dependencies and occur to differing degrees. Analysis of the dependencies involved and the flexibility that this implies will add to our general comprehension of the visual system and its relation to other sense modalities.

References

- HARRIS, C. S. Adaptation to displaced vision: visual, motor, or proprioceptive change. *Science*, 1963, 140, 812-813.
- HAY, J. C., PICK, H. L., JR., & ROSSER, EDWINNA. Adaptation to chromatic aberration in the human visual system. *Science*, 1963, 141, 167-169.
- HELD, R., & HEIN, A. V. Adaptation of disarranged hand-eye coordination contingent upon reafferent stimulation. *Percept. mot. Skills*, 1958, 8, 87-90.
- HELD, R., & BOSSOM, J. Neonatal deprivation and adult rearrangement. Complementary techniques for analyzing plastic sensory-motor coordinations. *J. comp. physiol. Psychol.*, 1961, 54, 33-37.
- HELD R., & GOTTLIEB, N. Technique for studying adaptation to disarranged hand-eye coordination. *Percept. mot. Skills*, 1958, 8, 83-86.
- KOHLER, I. Experiments with goggles. *Scient. Amer.*, 1962, 206(5), 62-86.
- PICK, H. L., JR., HAY, J. C., & PABST, JOAN. Kinesthetic adaptation to visual distortion. Unpublished paper presented at Midwestern Psychological Association Meetings, May 1963.
- SMITH, K. U., SMITH, W. M. Perception and motion. Philadelphia: Saunders, 1962.

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