Interocular Effects in Prism Adaptation

Abstract. *Monocular prism aftereffects were measured in three groups of subjects each of whom had walked about wearing a 20-diopter prism, base up, over the right eye and one of the following over the left eye: a diffusing screen, 0-diopter prism, or a 20-diopter prism, base down. The performance of the third group showed that visual-motor spatial coordination in the adult is subject to at least limited interocular independence.*

Work on interocular effects in prism adaptation appears to have been limited to studies of interocular transfer. In this type of experiment one eye is occluded during the prism exposure. Adaptation is measured by monocular testing of the eye over which the prism was worn (the exposed eye), while transfer is measured by monocular testing of the eye which was occluded (the occluded eye). If the amount of compensation measurable in the latter case is less than in the former, then incomplete transfer is said to have occurred.

Two studies of this type with adult human subjects who wore laterally displacing prisms report complete interocular transfer of compensation for the displacement (*1*). Ebenholtz (*2*) measured incomplete transfer in adult humans who wore 10° tilting prisms for half an hour, but the effect was confounded with decay of adaptation, which is known to be rapid (*3*). Pick, Hay, and Willoughby (*4*) reported substantial interocular transfer of adaptation to gaze-contingent effects of wedge prisms, that is, stretching and tilting. We have found complete interocular transfer of adaptation to wedge prisms worn with the base up over the right eye. One group wore a 20-diopter prism and the other a 10-diopter prism. Transfer was complete throughout an accumulated exposure period during which tests were given at 0, 2, 4, 8, 16, 32, and 64 minutes (*5*).

Incomplete interocular transfer in the intact human adult would be surprising, especially because of the report by Bossom and Hamilton (*6*) that complete transfer of compensation for lateral displacement was obtained in split-brain monkeys. In contrast, Held and Hein (*7*, *8*) have consistently found failure of interocular transfer in certain visual-motor coordinations in kittens. Held (*8*) regards these observations as an important breakdown in the "complementarity hypothesis," because the evidence points to complete interocular transfer in adult adaptation to rearrangement. But interocular transfer experiments of these types may not be the most powerful way of examining interocular effects in the adult. Occlusion of one eye is only one of a number of procedures which provide different exposure histories for the eyes. We have compared this condition with two additional procedures in which both eyes are exposed during training, but different prism strengths or different base directions are used concurrently. Many variants of these conditions are possible. We chose to begin by treating the right eye identically in each of three groups of subjects by using a 20-diopter prism, base up. The left eye treatment varied among groups. It was either occluded (*9*) (condition 1), exposed through plane glass (condition 2), or exposed through a 20-diopter prism, base down (condition 3). We were interested in what effect the treatment of the left eye would have upon right-eye measures and also in whether right- and left-eye measures would differ under any of these conditions.

The subjects in our experiment were female undergraduates who were randomly assigned to 3 groups of 12 each. Each subject walked along corridors in the building for a total of 15 minutes while wearing the appropriate combination of prisms mounted on an opaque face in a modified diving mask. The monocular visual field was circular and measured about 70°. Before the exposure began and after each 5 minutes, monocular tests of eye-hand coordination were conducted with the goggles off. On a test trial the subject sat with head fixed by a chin rest and bite bar, and positioned an unseen sliding horizontal rod to the apparent height of a dim 42-minute test light 50 cm ahead of her in a dark field. Most judgments were of a target (T) approximately 8½° below the subject's horizon, but dummies randomly selected from two higher and two lower targets within 6° of the central one were also presented. Twelve trials were given at each test session, a table of random permutations being used to intermix four T and two dummy presentations to each eye.

Performance on the T presentations at 5, 10, and 15 minutes was expressed as an angular shift from performance before the test for a given eye in each subject (aftereffect) (Fig. 1). An upward shift would be adaptive for the right eye in all cases, and a downward

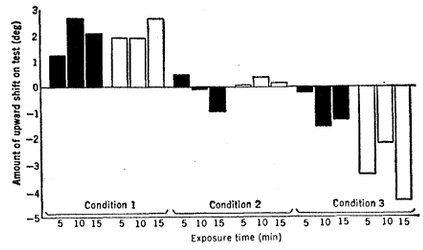

Fig. 1. Shift in height judgment after three 5-minute exposure periods in three groups subjected to different exposure conditions. Right-eye performance is shown by solid bars, left-eye performance shown by open bars.

shift for the left eye in condition 3. Complete compensation demands a shift of about 11°. Analysis of variance of the aftereffect measures indicated that exposures continuing after the first 5 minutes did not produce appreciable changes in performance. The main effect of condition [$F(2,33) = 5.07$, $P < .05$] must be interpreted in the light of an obtained condition times eye interaction [$F(2,165) = 6.26$, $P < .01$].

The form of the interaction is evident from Fig. 1. Condition 1 (occluded left eye) produces an upward shift and complete interocular transfer. Condition 2 (left eye with plane glass) also produces right- and left-eye measures which are alike, except that judgments are unchanged from performance before the test (no aftereffect). The group assigned to condition 3 (left eye reversed displacement) is the only one to show effects on performance associated with the eye used in testing [$t(165) = 5.5$, $P < .001$]. Measures from the left eye show an adaptive downward shift. The downward shift measured in the right eye is not significantly different from zero [$t(33) = .73$].

The performance of subjects in condition 3 indicates that "channel-dependent" effects can be produced in adult rearrangement studies. It is evident from the performance observed under condition 2 that this will not necessarily be achieved by all arrangements which provide simultaneous differential exposure of the eyes. Even in condition 3 the independence of the eyes is not complete, since judgments made with the right eye do not show aftereffects consistent with the base direction of the prism used. A model of interocular interaction in visual-motor coordination must therefore be concerned with both the possibilities of and limitations upon independence. Condition 2 suggests that "normalcy" (consistency with past experience) may be one important limiting determinant.

Also, in conditions 2 and 3, the left eye sees more of the floor than the right, and this might contribute to the evident potency of the left-eye treatment. Ocular dominance was measured in all of our subjects but the results of right- and left-eye dominant individuals were not notably different.

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5. The measured compensatory shift in judgment was found to increase for about the first 8 minutes and then level off. The 10-diopter group achieved only about half the magnitude of shift observed in the 20-diopter group. In both cases compensation was considerably less than complete. Similar effects for adaptation to tilting prisms have been reported by S. M. Ebenholtz [*J. Exp. Psychol.* **72**, 629 (1966)].
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9. A diffusing material which transmitted 96 percent of incident light without allowing pattern vision was mounted over the left eye.
10. Supported by National Research Council of Canada grant APA-1.

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Carcinogenicity of Tobacco-Smoke Constituents

In their work on experimental carcinogenesis by constituents of tobacco smoke, Wynder and Hoffmann (*1*) have relied heavily on mouse skin assays for their conclusions concerning carcinogenicity. Although they point out that study of the respiratory epithelium may be preferable, they conclude that it is not suitable for routine studies, and they also conclude that "mouse epidermis adequately represents various epithelial surfaces susceptible to carcinogens on contact." Their work has dealt largely with assaying hydrocarbon fractions of tobacco smoke condensate, and they believe that polynuclear aromatic hydrocarbons are the main tumor initiators in the condensate.

The suitability of mouse skin for assaying carcinogenicity of tobacco smoke constituents on the bronchial epithelium can be questioned on several grounds. For example, the role of alpha-emitting radioisotopes such as polonium-210 (*2*) could not have been assessed by this technique, since the alpha particles have a limited range of 40 microns or less in tissue. Thus they would not be likely to penetrate to the deep dividing cell layer of skin, but they can penetrate the respiratory epithelium to the more superficial basal layer of stem cells.

In their review, Wynder and Hoffmann state that ^{210}Po may be of importance as a carcinogen only in relatively high concentrations. The implication is that low tissue concentrations that result from smoking are unimportant, and they cite calculations by Rajewsky and Stahlhofen (*3*) indicating that polonium from cigarette smoke on the surface layers of mucus results in low radiation doses to epithelium. Wynder and Hoffmann's discussion of this subject does not include mention of our measurements of actual polonium concentrations in bronchial tissues of 25 smokers (*4*). We have commented previously on Rajewsky and Stahlhofen's conclusions (*5*), and have shown that their techniques were not capable of detecting "hot spots" such as we have found at bronchial bifurcations. The other paper cited by Wynder and Hoffmann relative to this question —Casarett's brief review (*6*)—is chiefly concerned with other effects of radiation on pulmonary tissues, with only passing mention of the carcinogenic possibilities.

Wynder and Hoffmann also failed to mention an experimental study by Yuile and his co-workers (*7*), who showed that bronchial squamous cell carcinomas developed in rats 2 years or less after a single exposure to polonium aerosol, with cumulative lung doses from 70 to 540 rads. Exposure, in uranium mines, to alpha radiation from radon daughters is now generally accepted as an etiological factor in the genesis of bronchial cancer in miners. In these cases relatively low doses of radiation appear to be significant (*8*). These studies in miners, as well as the experimental evidence, support the view that radiation exposure from polonium in cigarette smoke continues to warrant serious consideration as an important carcinogen.

The question at issue is how much any particular component of cigarette smoke can be implicated in the increased incidence of bronchogenic carcinoma in cigarette smokers. We believe that assigning the extent of causation to any particular agent will be difficult indeed. If cigarettes can be made which remove one or more of these suspected components from smoke, many years of very careful evaluation will be required to show whether such removal has had a significant effect on the incidence of bronchial cancer. Identification of the causative agent or agents in cigarette smoke is nevertheless of great importance, in view of the fact that the general public may be exposed to such agents from sources unrelated to cigarette smoking—for example, from general environmental contamination with radionuclides or aromatic hydrocarbons as air pollutants.

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The evidence that polonium-210 plays a role of any importance in tobacco carcinogenesis must still be considered inadequate. Little and Radford's finding (*1*) that a significantly