



Figure 1 (Mikaelian). The upper pair of scenes are shown as viewed normally, the lower pair as viewed through a wedge prism. The left-hand scene, with its linearly ordered contours, appears curved and distorted by the prism; whereas, the right-hand scene, composed of randomized spots, appears unchanged. (Reprinted with permission of M.I.T. Press.)

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*Adaptation of the distortion of shape is different from adaptation to the distortion of space.* The sharp difference between the H & R results and Gyr et al.'s attempted replication is another instance of conflicting results from similar experiments, a situation not that uncommon in prism studies, and one that probably arises from subtle differences in procedural or equipment details that workers fail to report. Gyr et al. offer an elegant and critical analysis of the implications of the H & R study. Held and his co-workers interpreted their early prism studies as instances of the involvement of the motor system in vision, with many of the investigators preferring to use the term "perceptuo-motor" response when referring to the perceptual responses being investigated (such as shape, distance, orientation, localization, etc.). Most of these studies were conducted within a conceptual framework that considered perception to be a unitary process, and it was assumed that adaptation to rearrangement of visual space followed the same rules, whether one considered adaptation to the distortion of shape, spatial localization, or other variables (all induced by wedge prisms).

A major difference between adaptation to the distortion of shape and to spatial localization was evident, however. Prolonged active viewing through prisms produced curvature after-effects that were a small fraction of the prism-induced curvature (Kohler 1964) and comparable to those obtained by passively viewing an array of curved lines (Gibson 1933 *op. cit.*). Full and exact compensation to the visual displacement could, of course, be obtained (Held & Bossom 1961).

The possibility that there may be two processes operating in adaptation to rearrangement was discussed in a subsequent paper by Mikaelian & Held (1964), although these discussions were in relation to adaptation to prism-induced visual tilt.

In later papers Held expanded on his formulation of the extent of the involvement of the motor system in the processing of shape (Held & Hein 1967; Held 1970). Along with other investigators (Ingle 1967; Schneider 1969; Trevarthen 1968) he suggested a dual process in the analysis of spatially-distributed stimulation, referring to the dual modes as "identification" and "localization" (Held 1968). Processing of shape information was ascribed to the

"identification" mode of stimulus analysis; its processing was more or less hard-wired, its plasticity limited, and its operation dependent upon such cortical units as edge detectors, feature analyzers, and so forth. Beyond a critical period, developmental influences on these processes were said to be limited. In contrast, the "localization" mode of processing, which mediated information such as position relative to the environment, movement of self vs. the environment, orientation or distance in space, and so forth, was said to be highly labile and integrally related to the sensory motor system. Held suggested that rearrangement experiments were relevant primarily to the latter category of perceptual responses.

Considering such a dual mode and the conditions that evoke one or the other mode of analysis of spatially-distributed stimuli, this commentator is not surprised that Gyr et al. were unable to obtain reliable curvature after-effects. Stimulus-contour (or texture) density is an important variable in invoking one or the other mode of analyzing the visual array (Held 1970), with impoverishment favoring the locus-specific mode of operation. Gyr et al.'s experimental condition drastically reduced the relevant reafferent information (due to the low density of viewing contours), which, added to the limited modifiability of form perception, produced the observed results. An illustration of the very high-density random-dot spot field used in the H & R study may be found in Held & Hein (1967). (It is unfortunate that H & R did not publish this information in their original article.) [See figure 1.]

In replicating prism studies, or in designing new ones, useful information can be gained by making a distinction between the dual modes of processing spatially-distributed stimuli. I would hazard a guess that if, in addition to curvature, Gyr et al. had measured egocentric localizations, they would have obtained significant adaptive alterations.

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*Visual-motor conflict resolved by motor adaptation without perceptual change.* In their closing comments Gyr et al. suggest that the sensorimotor model may be more readily validated for situations in which an experimentally-produced conflict cannot be ignored but must be resolved by the subject. Measurement of

motor adaptation, which might provide one kind of evidence for conflict resolution, is, unfortunately, absent from both the Held & Rekohs (1963 *op. cit.*) study and from Gyr et al.'s replication. Such measurements have been obtained in an adaptation study by Miller & Festinger (1977), which involved conflict between the shape of a visually presented curve and the pattern of eye movements necessary to scan that curve.

Briefly, the experiment was as follows. Subjects viewed a computer-generated display consisting of horizontally-oriented, concave-up curved lines. The position of these curves was contingent on the horizontal position of the eye so that, in order to scan a curve errorlessly, the eye would have to execute purely horizontal saccades. In one condition this was achieved by moving the curves vertically so that the point fixated always had the same vertical location. Eye movements were reprogrammed rapidly to eliminate the vertical components of the saccades that were present at the start. Thus, subjects did effectively deal with the sensorimotor conflict. There was, however, no change in the perception of curvature in excess of that measured following equivalent viewing of a stationary display (i.e. the Gibson normalization effect). In another condition the eye-position-contingent display was again moved vertically, but in such a way that the vertical components of scanning movements would need to be double what is normal for fixations to be accurate. Again, eye movements were rapidly and appropriately adjusted and, again, there was no perceptual change in excess of normalization. In yet another condition the curves were displaced horizontally so as to simulate the effect of viewing a straight line through a base-down wedge prism on a contact lens. A small amount of perceptual adaptation in excess of normalization was found in this condition, but it was quite unrelated to oculomotor retraining and apparently due to some property of the stimulus situation.

Thus, this experiment implies that, at least with the afferent visual and oculomotor systems, sensorimotor conflict is resolved by altering motor programs without altering either perception or, presumably, afferent visual processing. This position is consistent with that of Harris (1965 *op. cit.*), who concludes that in such conflict situations it is the felt positions of body parts that change, and not visual perception.

It is possible that information based on relative retinal location is essentially unalterable and dominates other conflicting sources of information. If this is true, perceptual adaptation to sensorimotor conflict may only be possible for cases in which such intravisual information is not involved.