

Table 2. Activity of uterine phosphorylase *a* and *t* after intraperitoneal injections of 0.6 millimole of EDTA or its calcium salt per kilogram of body weight. Reported in micrograms of P as in Table 1. The values given are the mean of at least four determinations with $\pm$ S.E. of mean.

Phosphorylase activity (μ g P)		Ratio (<i>a/t</i>) $\times$ 100
<i>a</i>	<i>t</i>	
	Control	
83 $\pm$ 12	308 $\pm$ 21	26.7 $\pm$ 2.9
	EDTA	
165* $\pm$ 8	258 $\pm$ 9	64.2* $\pm$ 3.1
	Ca salt of EDTA	
212* $\pm$ 8	305 $\pm$ 6	69.9* $\pm$ 1.8
	NaCl†	
115 $\pm$ 11	342 $\pm$ 7	33.2 $\pm$ 2.8

* $P < .001$; † Same osmotic pressure as the Ca salt of EDTA.

solution (3). Therefore we injected EDTA and its calcium salt (0.6 mmole/kg of body weight in 1 ml volume at pH 7.3) intraperitoneally into spayed female rats and determined the uterine-phosphorylase activity. As a control, enzyme determinations were also made on uteri from rats injected with a solution of NaCl equiosmotic with the solution of the calcium salt of EDTA. The results (Table 2) show that there was a significant increase in phosphorylase *a* activity and the *a/t* ratio with both EDTA and its calcium salt but not with NaCl.

Adaptation to Displaced Vision: Visual, Motor, or Proprioceptive Change?

Abstract. *After seeing his hand through wedge prisms, a subject points incorrectly with that hand at auditory as well as visual targets. The other hand is virtually unaffected. Thus the change cannot be solely visuo-motor or visual. Other evidence suggests that it is a change in felt hand location, rather than motor learning. When the subject's adapted hand feels as if it is pointing straight ahead, for example, it is actually pointing off to one side.*

When the images on a person's retinas are inverted, reversed, or displaced from their normal positions, the person at first misses when he reaches for objects. After some practice, he "adapts" and reaches more accurately (1).

Despite widespread interest in this adaptation and its implications, there has been no general agreement on the nature of the adaptation—on how the person who has adapted differs from one who has not. Even careful introspection provides no clear-cut answer: the detailed diary that Stratton kept while adapting to inverted vision (2) has sometimes been quoted to show that he experienced a shift in visual perception, sometimes to show that the only change was behavioral.

The increase in phosphorylase *a* activity with EDTA is not a universal property of smooth muscle since the phosphorylase *a* activity of taenia coli muscle from guinea pigs, homogenized in NaF and EDTA, was 220 μ g of P per 100 mg of tissue while the activity of those homogenized in NaF alone was 400 μ g of P (average of four assays, $P < .001$).

Since EDTA did not increase the total phosphorylase activity, the activation appears to result from a conversion of the inactive form to the active form of the enzyme. However, the mechanism of activation of uterine phosphorylase by EDTA is unknown at present and it appears to be unlike that reported for any other tissue (4).

H. PHILIP SCHANE

S. L. LEONARD

Department of Zoology, Cornell
University, Ithaca, New York

References and Notes

1. E. G. Krebs and E. H. Fischer, *J. Biol. Chem.* **216**, 113 (1955); *Ann. N.Y. Acad. Sci.* **88**, 278 (1960).
2. S. L. Leonard, *Endocrinology* **60**, 619 (1957); *ibid.* **63**, 853 (1958).
3. H. Foreman, M. Vier, M. Magee, *J. Biol. Chem.* **203**, 1045 (1953).
4. Supported in part by grants from the National Institute of Arthritis and Metabolic Diseases [A4965 (C1)] and the Muscular Dystrophy Associations of America, Inc.

11 February 1963

top was slightly below his eye level. His head was held immobile by a bite-board. His task was to point (with his arm extended under the tabletop) at one of five rods sticking up from the tabletop, or at the sound of a clicker, or "straight ahead." The rods were spaced 4 inches apart in a row perpendicular to the subject's line of sight, with the central rod directly in front of his nose and 24 inches away from it. The clicker was held immediately behind one of the three middle rods, about 2 inches above the tabletop.

Before adapting, the subject pointed three times with each hand at each of the five visual targets, five times with each hand at each of the three auditory targets, and six times "straight ahead" with each hand. He did the same after adapting. Each subject pointed at the targets in a different mixed order determined by the experimenter. While pointing straight ahead or at the sound, the subject kept his eyes closed. When he pointed at the visual targets, an opaque cloth thrown over the table kept him from seeing his hand and arm.

While the subject was adapting, the opaque cloth was removed so that he could see his hand. He adapted for 3 minutes by pointing at the central visual target 90 times while wearing prisms that displaced his retinal images about 11° to the right or left. No fixation point was designated. Two subjects pointed only with their right hands while wearing the prisms base-left; two with right hands, prisms base-right; and two with each of the other two hand-prism combinations. The pointing motion was stereotyped: the subject started with his hand on a crossbar above his lap, from which he shot it forward and up, hitting the underside of the tabletop with the top of his forefinger. All subjects at first missed the target, but quickly became more accurate.

Table 1 presents the mean differences between measurements taken before and after adaptation (4). The measure was the point of intersection of the row of visual targets with a line from the subject's nose through his fingertip, as seen on photographs taken by an overhead camera.

It is clear that the adaptation effect transfers to all targets, regardless of their modality, but there is little or no transfer to the unadapted hand (5). Other investigators have also found that the effect does not transfer from the adapted to the unadapted hand in human beings (6, 7) and in normal and "split-brain" monkeys (6).

Table 1. Mean difference in inches between measures taken before and after adaptation (eight subjects). Positive changes compensate for the displacement, about 4.6 inches, caused by the prisms.

Target	Adapted hand	Unadapted hand
Visual	+2.3*	+0.4†
Auditory	+2.0*	—0.2
"Straight ahead"	+2.2‡	+0.2

* Significantly different from zero by two-tailed t test ($P < .0001$). † $.04 < P < .05$. ‡ $P < .01$.

These findings can be used to evaluate various interpretations of adaptation to displaced vision.

The simplest explanation is that after seeing that he has missed a target, a person deliberately corrects his aim the next time he points. When the prisms are removed, however, he should abandon such corrections. Indeed, most subjects said that when the prisms were removed they "went back to pointing right at the target." But Table 1 reveals that they did not in fact go back to pointing as they had pointed before adaptation. Rather, they consistently missed with their adapted hands. Clearly, then, the adaptation is not a conscious process.

Is the adaptation a change in visual perception? After practice with prisms on, does an object whose image is centered on the retina look as if it's off to one side? If so, the subjects would point at the same spot with either hand, as they did before adapting. But after adapting they pointed at two different spots, an average of 1.8 inches apart in the expected direction. (This difference was significant at the .0005 level. The corresponding difference before adaptation, 0.1 inch in the other direction, was not significantly different from zero.)

Since prisms alter only visual feedback from arm movements, one might suppose that adaptation affects only the correlation between behavior and vision. However, such terms as "changes in hand-eye coordination" and "changes in visually guided behavior" prove misleading. They imply that the adaptation is confined to visual targets. But, as Table 1 shows, the measured adaptation was the same whether the target was given visually or through other modalities. Thus, this adaptation is more than a visuo-motor change.

Two plausible interpretations fit the data so far presented. Both imply that the nature of the target is unimportant, but that it is crucial which hand is used in pointing at it.

The adaptation may be a change in proprioceptive perception—when a person's adapted arm is really pointing straight ahead, it feels as if it's off to one side. Or the adaptation may be motor learning—to point at a given target, the person learns to use a new pattern of muscle contractions.

A simple motor-learning model would suggest that the particular arm movement used is important. Whenever the subject uses an arm movement different from the one he practiced with, there should be at least some generalization decrement—the measured adaptation should be less than when he uses the well-practiced movement. In the present experiment, subjects adapted by pointing directly and rapidly at a target straight ahead of them. When they modified the arm motion in order to point at other targets, the measured adaptation was, if anything, greater than when they pointed at the target they had practiced on. The average amount of adaptation on each visual target, from left to right, was 5.5°, 5.1°, 4.9°, 5.3°, and 5.1°.

Indeed, adaptation cannot consist solely of learning a new muscle response to a particular perceived target location. For if proprioception remained unchanged, what would happen when a person completed the new arm movement? If he were kept from seeing his arm, as in the experiment reported here, he would feel that his hand hadn't reached the location he had aimed at. He would move it until the felt location of his hand matched the perceived location of the target. The result would be no measured adaptation.

But Table 1 shows that when the person could not see his adapted hand, he pointed off to one side of the target when he felt that he was pointing right at it. In fact, when suddenly allowed to see where they were pointing, most subjects expressed surprise. They did not see their hands where they expected to see them.

Thus, this rapid adaptation to displaced vision must involve a change in the felt position of the arm relative to the body. When proprioception and vision provide conflicting information—when a person feels his hand in one place and sees it in another—proprioception gives way. The person comes to feel that his hand is where it looks as if it is (8).

CHARLES S. HARRIS
Department of Psychology,
Harvard University,
Cambridge 38, Massachusetts

References and Notes

1. For an extensive review of experiments on adaptation to distorted vision, see K. U. Smith and W. M. Smith, *Perception and Motion* (Saunders, Philadelphia, 1962). Recent experiments are discussed in the same book, and in J. G. Taylor, *The Behavioral Basis of Perception* (Yale Univ. Press, New Haven, Conn., 1962), and in R. Held, *J. Nervous Mental Disease* **132**, 26 (1961).
2. G. M. Stratton, *Psychol. Rev.* **4**, 463 (1897).
3. H. von Helmholtz, *Treatise on Physiological Optics*, translated from the 3rd German edition, J. P. C. Southall, Ed. (Dover, New York, 1962), vol. 3, sect. 29; R. Held and A. V. Hein, *Perceptual Motor Skills* **8**, 87 (1958).
4. These measurements were recorded while the subjects were not wearing prisms. Using a somewhat different procedure, Hamilton has found that subjects show no more inter-manual transfer while looking through prisms than they do after the prisms are removed (6).
5. The subjects' mean standard deviations of pre-adaptation responses to the visual, auditory, and "straight ahead" targets were, respectively, 0.37, 1.51, and 0.42 inches. After adaptation, the corresponding figures were 0.35, 1.21 and 0.73 for the adapted hand; 0.33, 1.32 and 0.55 for the unadapted hand.
6. C. R. Hamilton, in preparation.
7. H. Mikaelian, paper scheduled to be read at convention of the Eastern Psychological Association (1963).
8. A portion of this work was done at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology with the joint support of the U.S. Army, Navy, and Air Force. Preliminary research was carried out at the Center for Cognitive Studies and the Psychological Laboratories, Harvard University.

21 February 1963

Hypoxia: Effects on Heart Rate and Respiration in the Snapping Turtle

Abstract. *In response to atmospheres containing decreasing amounts of oxygen, snapping turtles (Chelydra serpentina) maintained a fairly constant oxygen uptake. Their heart rate increased and the period of apnea between breathing cycles decreased. Small animals had a slightly greater mean uptake per gram than those five to ten times as large.*

Turtles are especially tolerant of low levels of oxygen (1), and since *Chelydra serpentina* is one of the most aquatic of fresh-water species, it was selected for a series of studies of hypoxia at ambient oxygen levels from 21 to 2 percent.

Thirteen specimens weighing 82 to 1433 g were maintained in tanks of shallow water at 24° to 26°C, on a weekly diet of horsemeat. Each turtle was fasted for at least 4 days before it was tested. An open-circuit, constant-flow system, with the animal chamber (dry) maintained at 25°C, was used; a Beckman paramagnetic oxygen analyzer sampled the outlet gas to measure oxygen consumption at standard temperature and pressure (2). Flow rates