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*).

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References and Notes

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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 intermanual 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.
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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.

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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 depending on the size of the animal and the volume of the chamber ranged from 60 to 150 cm^3/min. Inlet gases (except room air) were made up in Douglas bags to an accuracy of ± 0.4 percent O_2. Pressures in the animal chamber were approximately 740 mm-Hg. Variations in the pressure of oxygen (P_{O_2}), which resulted from barometric and water vapor effects, were less than those allowed in making up the original mixtures. Therefore, the oxygen percentages were considered easier to use in tabulating results. Electrocardiograms (ECG) were taken with a high-gain preamplifier and a polygraph, with lengths of stranded copper wire wrapped around three legs as leads and ground. Breathing records were obtained in some of the experiments with the ECG leads and an impedance pneumograph (*3*) on a second channel. An interval of 1 to 3 hours was allowed to equilibrate the apparatus and quiet the animals. Because turtles have irregular breathing and long periods of apnea, respiration was monitored for as long as several hours.

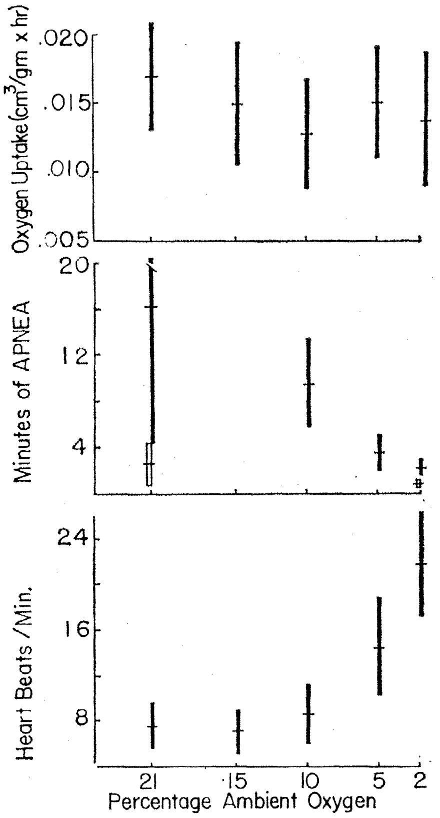

Fig. 1. Effects of decreasing ambient oxygen levels on oxygen uptake, period of apnea between breathing cycles, and heart rate. The vertical bars show 95 percent confidence intervals; the horizontal dashes, the means. Each bar represents 13 animals except in the graph for the period of apnea where the open bars represent the five animals weighing under 200 g, the solid bars the six weighing over 1000 g.

Table 1. Mean oxygen pulse values of 13 turtles at varying oxygen levels.

Oxygen (%)	Oxygen pulse (10^{-5} cm^2/beat × g)
21	3.67
15	3.47
10	2.47
5	1.73
2	1.07

The effects of five decreasing levels of ambient oxygen upon oxygen uptake, period of apnea between breathing cycles, and heart rate are shown in Fig. 1. There were no significant differences in oxygen uptake at the various levels. Comparing the combined data for the five turtles weighing under 200 g with data for those over 1000 g shows that the smaller animals have a significantly higher uptake when all percentages are combined ($P < .001$). These differences were not significant ($P > .05$) when the two lowest oxygen levels were tested separately; in contrast, they were significant for separate tests of the three high levels. The difficulty of showing a clear correlation between respiration and size in turtles has been noted elsewhere (*4*).

At levels of both 21 and 2 percent oxygen the small turtles had much shorter periods of apnea than the large ones. The smaller animals had significantly faster heart rates in room air ($P < .01$), but the rates were not significantly different at other oxygen levels (except at 5 percent).

A regression analysis of oxygen uptake as a dependent variable on heart rate was calculated for the group of 13 animals at each oxygen level by the familiar

$$Y = a_y + b_{yx}(X).$$

The five b_{yx} values were significantly different from zero (that is, regression was actually present) but not from each other. Yet as Table 1 shows, the relation of oxygen uptake to heart rate (oxygen pulse) shows a consistent decrease with decreasing ambient oxygen levels. The oxygen pulse at room air is similar to that given for a lizard, *Eumeces obsoletus* (*5*), despite great dissimilarity in both heart rate and oxygen uptake.

The maintenance of oxygen uptake under hypoxia can be correlated with the decreased period of apnea and the increased heart rate, since these changes would move the available oxygen faster to the tissues. How the turtles can tolerate such a low uptake may possibly be explained by their utilization of anaerobic metabolism (*6*), and by their breathing cycle which has a strong compression phase (*7*) increasing lung P_{O_2}. Comparison of oxygen dissociation curves of the hemoglobin of the snapping turtle (*8*) with those of other reptiles does not suggest any greater loading efficiency for this or other species of turtles.

Since turtles show changing blood values of CO_2 and pH with changing temperature, their control of breathing may not depend on these factors (*9*), and since they respond to rapidly increasing or decreasing ambient oxygen levels with changes in heart rate and period of apnea in as little as 1 minute, the oxygen tension of the blood may be a factor in the control of breathing, especially when the other factors depend on temperature (*10*).

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Repeatability of Jupiter's Decametric Radio Emission

Dynamic spectra of Jupiter's decametric emission show that the planet has a permanent dynamic spectrum. This report discusses a recent outstanding series of events where this feature is particularly clear.

Jupiter's sporadic emission at low frequencies is notable for the stability with which events occur in definite longitude ranges [near 100°, 200°, and 300° in the radio longitude system (*1*)]. This directivity was recognized very soon after the discovery of the emission, and has been discussed widely in the literature (*2*).

The first dynamic spectra (*3*) of Jupiter's low-frequency emission ex-