F-2 area ($P < .01$ for both correlations).

Increased PDH activity results from a decreased phosphorylation of the enzyme (*11*); we have demonstrated this relationship in the brain (*12*). With precautions taken to preserve the phosphorylation in vivo and the enzyme activity state (*7, 8*), increased phosphorylation of PDH (band F-2) in vitro in trained animals reflects a reduced phosphorylation of PDH in vivo. We conclude that the training-induced increase in frontal cortex PDH activity occurs after a dephosphorylation of PDH in vivo.

Training-induced alterations in brain PDH may regulate synaptic function. This could involve synthesis of transmitters such as acetylcholine (via acetyl coenzyme A) and glutamate (via the tricarboxylic acid cycle) (*13*) in response to synaptic activation after repetitive stimulation (*14*). Moreover, insulin, which is localized to presynaptic terminals (*15*), can induce an increase in PDH activity (*16*), by stimulating PDH phosphatase through a peptide intermediary (*17*). It is possible that such peptide second messengers alter the brain PDH activity observed 24 hours after training (*3*).

These considerations suggest that brain PDH, through a phosphorylation-dephosphorylation cycle, is sensitive to manipulations of brain activity and may initiate or participate in the biochemical response of the cells involved in the neuronal plasticity of learning and memory (*18*).

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6. ———, *Brain Res.* **179**, 329 (1979). Groups 3 and 4 (shocked only and handled only) are referred to here as not trained, although some learning, not related to step-down training, occurred.
7. Liquid nitrogen immersion prevents the rapid dephosphorylation of PDH observed after decapitation [R. Jope and J. P. Blass, *J. Neurochem.* **26**, 709 (1976)]. We have never observed a training effect on band F-2 after decapitation, probably because of this rapid dephosphorylation. For a comparison of the liquid nitrogen and decapitation methods, see R. G. Conway and A. Routtenberg [*Brain Res.* **139**, 366 (1978)]. In a recent study (22), dephosphorylation at 0°C was less than 10 percent, even after 1 hour. Although more rapid methods are available for brain enzyme fixation [J. V. Passonneau, R. A. Hawkins, W. D. Lust, F. A. Welsh, *Cerebral Metabolism and Neural Function* (Williams & Wilkins, Baltimore, 1980) pp. 10–19], these are not compatible with brain dissection and regional analysis. With adult rats frozen in liquid nitrogen, the frontal cortex would attain 0°C within 5 to 30 seconds, depending on the cortical layer.
8. The frontal cortex anterior to the caudate nucleus was removed bilaterally and homogenized, while still frozen, in 20 volumes of 30 m*M* potassium phosphate buffer (2°C, *p*H 7.2) with 1 m*M* EDTA to inhibit the PDH phosphatase. The homogenate was frozen in liquid nitrogen and thawed in the cold room to extract the PDH complex. The total time in a fluid state between homogenization and transfer to assay and reaction tubes was less than 5 minutes. These precautions were taken to minimize dephosphorylation of the PDH complex. Proteolysis was evaluated and not observed with five different protease inhibitors.
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Questions About Spatial Adaptation of Short-Wavelength Pathways in Humans

Stromeyer *et al.* (*1*) have reported color-selective spatial adaptation of the blue-sensitive visual pathway. They found that a violet adapting grating superposed on a circular yellow-green adapting field of uniform luminance decreased the detectability of violet (but not of red) test gratings of the same orientation and spatial frequency. This effect was strongly monocular. They tested two subjects under dichoptic conditions, one with alternating adapting and test gratings and the other with a continuously presented adapting grating. The first subject showed only slight (less than 10 percent) interocular transfer and the second showed none.

Stromeyer *et al.*'s study contains a flaw with regard to postreceptoral adaptation. Specifically, their subjects fixated the adapting field (presumably at its center, since no explicit fixation target is described) (*2*). This procedure almost certainly produced substantial patterned adaptation of the short-wavelength cones themselves (*3*). Such adaptation is expected to be selective for wavelength, spatial frequency, and orientation, just as Stromeyer *et al.* found.

The dichoptic results cannot be fully explained by either local retinal adaptation, which is strictly monocular, or by cortical spatial adaptation, which predicts strong interocular transfer. An alternative hypothesis is that the negative afterimage of the adapting grating in the alternating grating condition raised the test grating threshold by means of dichoptic opponent color cancellation (*4*). Under this hypothesis, the other subject would not have seen a comparable effect because the continuous adapting grating produced no negative afterimage.

Retinal adaptation, unlike central adaptation (*5*), depends on the relative spatial phases of the test and adapting gratings. Stromeyer *et al.* could therefore have checked for retinal artifacts by shifting the phase of the test grating by, say, 180°. Their figure 1, however, suggests that they used only test and adapting gratings of equal phase, the condition expected to produce the maximum retinal effect.

Whereas color-sensitive spatial adaptation of central visual pathways remains possible, Stromeyer *et al.*'s results can be easily explained without it.

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2. Long-term fixation accuracy is expected to be only slightly better for an optimal fixation target than for the center of the 4° diameter adapting field used by Stromeyer *et al.* [J. D. Rattle, *Opt. Acta* **16**, 183 (1969)].
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when subjects purposely try to avoid patterned retinal adaptation by scanning their eyes as randomly as possible over an adapting grating, the total exposure is equivalent to that from a stabilized grating of 12 to 25 times its threshold contrast. Although Stromeyer *et al.*'s fixation technique did not eliminate all eye movements, it nevertheless must have produced much stronger retinal adaptation patterns than Arend and Skavenski's scanning technique.

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We previously observed that prolonged adaptation to a vertical violet grating that was detected by the short-wavelength (S) cones raised the threshold of a vertical violet test grating but not a vertical red grating that was detected with the long-wavelength cones (*1*). The spatial adaptation was orientation selective and confined to the S-cone pathways. The gratings were 8 cycle/deg and covered a 4° yellow adapting field, used to isolate the S-cone pathways. The observer slowly scanned the central region (approximately 1°) of the adapting grating. The fine adapting grating "dissolved" after several minutes' viewing, and the field appeared fairly uniform.

Observers who are asked to uniformly scan a grating tend to fixate particular phases (*2*), even at 8 cycle/deg (*3*). Although our observer (C.F.S.) could barely see the faded adapting grating, he may have fixated systematically so that the retina was not homogeneously adapted (*4*). In order to eliminate local retinal adaptation we have done an additional experiment. We controlled the movement of the stimulus on the retina by compensating for eye movements and drifting the grating at a constant retinal velocity (*3*). Under these conditions we still obtained orientation-selective adaptation as strong as adaptation experienced during free viewing.

Violet (~ 450 nm) 4 cycle/deg gratings of constant mean intensity (8.80 log quanta deg^{-2} sec^{-1}, 23 trolands) covered a 4.3° diameter yellow (560 nm) field of 10.80 quanta deg^{-2} sec^{-1} (50,000 trolands). All gratings were either vertical drifting leftward or horizontal drifting upward at 0.5 deg/sec (2 Hz). Kelly and Burbeck (*3*) concluded that this rate of movement of a "stabilized" image is sufficient to minimize the effect of local retinal adaptation on spatial pattern adaptation. The adapting grating was presented for 5 seconds and alternated with the test grating, presented for 1.4 seconds. Each run consisted of 3 minutes of adaptation to this sequence followed by 70 to 100 trials. The adapting contrast was either zero or 90 percent. Three test contrasts (including blanks) were randomly intermixed in each run. A single adapting and test orientation was used in each run. The visibility of the test grating was measured with a signal detection method (*1*).

Eye position was monitored with a modified double-Purkinje-image eye tracker (*5*), and the grating was moved to cancel retinal image motion that would otherwise result from eye movements (*6*). The observer's right pupil was dilated, accommodation was paralyzed, and refraction was optimal for the violet pattern. An artificial pupil of 3 mm was placed in an optical relay system (*7*) in a plane conjugate to the natural pupil.

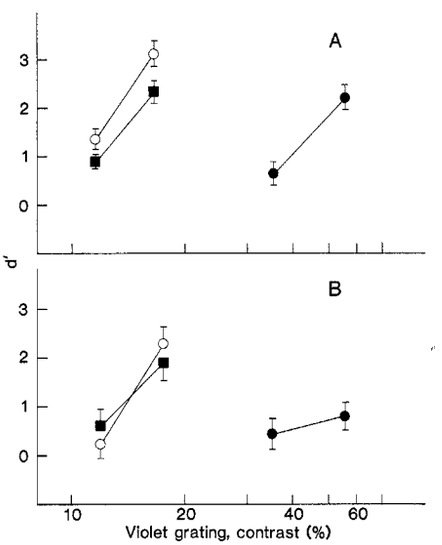

Fig. 1. Detectability ($d' \pm 1.0$ standard error) of 4 cycle/deg violet vertical (A) and horizontal (B) test gratings as function of contrast. Adaptation: uniform violet field (○); high-contrast 4 cycle/deg violet grating, same orientation as test grating (●) or orthogonal orientation (■). Gratings moved with retinal velocity of 0.5 deg/sec. Each curve is based on two or three runs in (A) and on one run in (B). Observer was C.F.S.

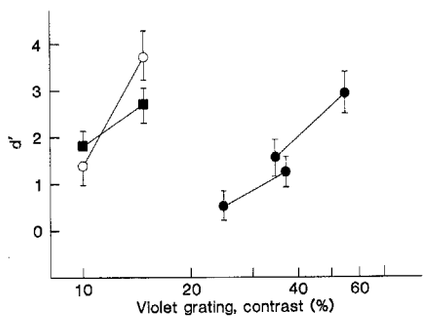

Fig. 2. Stimulus conditions as in Fig. 1A, but gratings were stationary and unstabilized. Each curve is based on one run.

A vertical adapting grating strongly reduced the detectability of a vertical test grating, whereas a horizontal grating had little effect on the same test grating (Fig. 1A); this orientation selectivity was also obtained with a horizontal test grating (Fig. 1B) (*8*). For comparison, Fig. 2 shows the results when orientation-selective adaptation was measured with stationary unstabilized gratings. The local retinal adaptation that may occur in this case did not markedly increase the effect obtained with drifting gratings (*9*).

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6. Sinusoidal gratings were generated on a monitor display (Tektronix 608) with a violet P11 phosphor. They were viewed through a 457-nm short-pass interference filter and achromatizing lens. When using drifting gratings, a diamond array of unstabilized black fixation dots was placed on the violet display. For the yellow field, a beam from a tungsten halogen lamp passed through an interference filter (560 nm, 9 nm full bandwidth at half maximum); this was combined with the violet light by a dichroic mirror. The head was restrained with a bite bar and forehead rests. Signals from the eye tracker were sampled at 100 Hz and used to redetermine the raster position both vertically and horizontally during the sweep blanking. The gain of the image stabilizer system was optimized as described by D. H. Kelly [*J. Opt. Soc. Am.* **69**, 1266 (1979)].
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8. Eye movements were recorded during the stabilized condition. The observer unconsciously made periodic horizontal saccades of ~ 0.5° during presentation of both vertical and horizontal moving adapting gratings; saccades were suppressed during the test phase. Vertical saccades were nonperiodic, smaller, and less frequent. Since horizontal saccades produce large temporal modulations of local retinal illuminance during presentation of a vertical grating but little modulation during presentation of a horizontal grating, the similarity of the results at the two orientations provides further evidence that the adaptation cannot be explained by the pattern of fixational eye movements and local retinal adaptation.
9. Moving gratings may produce strong orientation-selective adaptation in part by adapting direction- and velocity-selective mechanisms that are less affected while viewing stationary unstabilized patterns. Thus the comparable threshold elevations in Figs. 1 and 2 may in fact reflect the behavior of different populations of neurons.
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