11. J. W. Kebabian *et al.*, *Trends Pharmacol. Sci.* 7, 96 (1986).
12. R. E. Chipkin, L. C. Irio, V. L. Coffin, R. D. McQuade, J. G. Berger, A. Barnett, *J. Pharmacol. Exp. Ther.* **247**, 1093 (1988).
13. S. Funahashi, C. J. Bruce, P. S. Goldman-Rakic, *J. Neurophysiol.* **61**, 331 (1989).
14. ———, *Soc. Neurosci. Abstr.* **12**, 554 (1986).
15. In the ODR task, the monkeys fixated a central spot on a cathode-ray tube, and a visual cue came on for 0.3 s, followed by a delay period. The cue was presented randomly at one of several peripheral locations (n = 6 to 22, usually six locations), which were separated by 45° or 90° and whose eccentricities were 7° to 20° (usually 20°). After the delay period (1.5 to 6 s, but usually 5 s), the fixation spot was then extinguished, which instructed the monkeys to make a memory-guided saccade to the location that had been cued before the delay period. The correct response was rewarded by a drop of juice 0.2 s after the response. Trials were separated by an intertrial interval of 3.5 s. The control task was exactly the same as the ODR task except that the target remained on during the "delay" period, thus providing sensory guidance for saccade in the response period.
16. A micromanipulator on a cylinder mounting on the skull was used to insert the syringe into the cortex and to control it precise localization and relocalization in subsequent sessions. The spread of 3 μl of injected solution into the cerebral tissue is about 3 mm in diameter [R. D. Myers, *Psychol. Behav.* **1**, 171 (1966)].
17. The experimental sessions consisted of blocks of trials with a time length of 5 or 10 min. In each block, the monkey performed the ODR or control (CON) task, and the blocks associated with the CON task were intermixed with the blocks associated with the ODR task in most cases. The monkeys performed two to four CON and two to four ODR blocks before and at least four blocks of each task after the injection. The following behavioral parameters were examined: discrepancy between the target location and the end point of the saccade during the response period; the onset latency of the response after the onset of the go signal; trajectories of saccades; and amplitude and velocity of saccades. Velocity was measured from the amplitude and duration of the saccades. The predrug blocks were combined into one score for each task, and this predrug block was compared with every postdrug block by a one-way analysis of variance followed by the Newman-Keuls procedure for multiple comparisons. The data in Table 1 are for injections in which at least one ODR postdrug block differed significantly from the predrug block.
18. Bradykinesia (slowing of responses) is characteristic of Parkinson's disease, a disease in which DA loss in the neostriatum is the cardinal pathognomonic finding. Our result of an increased latency to respond in the ODR task indicates that slowing of at least some memory-guided responses might be attributable to cortical DA dysfunction.
19. S. Bischoff, M. Heinrich, J. M. Sountag, J. Krauss, *Eur. J. Pharmacol.* **129**, 367 (1986).
20. C. Kohler, H. Hall, S.-O. Orgen, L. Gawell, *Biochem. Pharmacol.* **34**, 2251 (1985).
21. Funahashi *et al.* (*13*) have recently identified at least five different types of neuronal processes associated with ODR performance, and D1 receptors might be selectively associated with only one or a subset of these.
22. B. Berger, P. Greengard, P. S. Goldman-Rakic, *Soc. Neurosci. Abstr.* **15**, 428 (1989).
23. Supported by National Institute of Mental Health grants MH44866 and MH38546.

16 July 1990; accepted 31 October 1990

Technical Comment

Form, Motion, and Binocular Rivalry

If one looks at two grossly dissimilar images—such as orthogonal gratings—through a stereo viewer, only one eye's field of vision is seen at a time. This phenomenon is called binocular rivalry (*1*). N. K. Logothetis and J. D. Schall (*2*) performed an ingenious experiment to explore the neural basis of binocular rivalry. A monkey looked at a downward-moving "conveyor belt" of horizontal stripes through one eye and at upward-moving horizontal stripes through the other eye. While the monkey "reported" rivalry by pressing the appropriate key, the electrical activity of direction-selective neurons in the middle temporal (MT) area in the superior temporal sulcus was monitored. One might suppose that neural responses corresponding to the suppressed image would be silenced while neurons corresponding to the other image would be active. Although 10% of the cells showed the expected suppression, in most neurons no simple suppression was observed—certainly nothing similar to the complete occlusion that occurs perceptually. Indeed, sometimes there was an enhancement of neural responses to the suppressed image.

One possible explanation for this neuronal response would be that rivalry is a "network" property that cannot be studied in single cells, but this statement is not useful, even if it were true. A second explanation would be that rivalry is not a complete occlusion of one eye's input at an early stage, rather, it occurs at multiple sites and can selectively involve some neural channels while sparing others (*3, 4*). For example, stereopsis can be experienced in the presence of "form rivalry" (*4, 5*) even though only one image is perceived at a time. In the case of downward-moving stripes for the left eye and upward for the right eye, it is true that only one image is seen at a time, but is this really "motion rivalry" caused by inhibition between motion channels within the MT area itself? Even though the stripes are horizontal for both eyes, at any given instant the stripes are likely to be vertically misaligned. This would tend to generate form rivalry by stimulating noncorresponding retinal points (*5*). Perhaps it is this form rivalry that gates neural motion signals (*6*)—there may be no motion rivalry per se occurring within the MT.

I did an experiment recently (*6*) to study these effects. After I viewed the "conveyor belt" display for several minutes, two motion after-effects were generated. On looking at the world with the right eye I perceived downward movement, and on looking with the left eye I perceived upward motion. What happened when I opened both eyes depended on what I looked at. A stationary grating (or any pattern) usually looked stationary—the brain simpy averaged the motion after-effects from both eyes. But on presenting diagonal, orthogonal, stationary gratings to both eyes—so that I experienced form rivalry—I experienced motion rivalry as well! The left eye perceived upward motion and the right eye perceived downward motion.

I conclude that the motion signals from the two eyes were averaged only when I looked at the same form with both eyes. If there was form rivalry, on the other hand, the motion signals inhibit each other. Apparently, what happened in the form channels influenced what happened in the motion channels. Since the MT area is concerned with motion rather than form, these results may explain why Logothetis *et al.* did not observe a simple suppression of one eye's motion signals. Indeed, our results suggest that the best place to look for rivalry would be in the "form area" DL, V4, or IT rather than in MT. The presence of rivalry in these areas might modulate the activity of cells in the MT area in complex ways or interact with cells in higher motion areas such as the medial superior temporal area rather than in the MT itself.

A third explanation would be in terms of the theory of F. H. C. Crick and C. Koch (*7*), according to which the basis of conscious visual awareness is the synchronization of 40HTZ oscillations (*8*). If one is aware of an object, the firing of all neurons that are simultaneously activated by that object alone becomes synchronized. This synchronization does not include other neurons that are activated by objects that one is not attending to. A reanalysis of the data of Logothetis and Schall to look for synchronized oscillations (rather than suppression) may therefore be worthwhile. Such data could provide a test for the hypothesis that synchronized oscillations are actually involved in consciousness and not merely in binding features together for object segmentation.

V. S. RAMACHANDRAN
Department of Psychology and

Neuroscience Program,
University of California at San Diego,
La Jolla, CA 92093–0109

REFERENCES

1. H. Von Helmholtz, *Physiological Optics* (Dover, New York, ed. 1, 1925); B. Julesz, *Foundations of Cyclopean Perception* (Univ. of Chicago Press, Chicago, IL, 1971); J. Myerson, F. Miezin, J. Allman, *Behav. Anal. Lett.* **1**, 149 (1981); R. Blake and R. Fox, *Nature* **249**, 488 (1974).
2. N. Logothetis and J. D. Schall, *Science* **245**, 761 (1989).
3. A. Treisman, *Q. J. Exp. Psychol.* **14**, 23 (1962).
4. V. S. Ramachandran, V. M. Rao, T. R. Vidyasagar, *Nature* **242**, 412 (1973).
5. L. Kaufman, *Sight and Mind* (Oxford Univ. Press, New York, 1974).
6. V. S. Ramachandran, in *The Artful Brain*, R. L. Gregory, J. Harris, P. Heard, Eds. (Oxford Univ. Press, Oxford, England, in press).
7. F. H. C. Crick and C. Koch, *Semin. Neurosci.* **2**, 263 (1990).
8. C. M. Gray, P. Konig, A. K. Engel, W. Singer, *Nature* **338**, 334 (1989); W. Singer, *Concepts Neurosci.* **1**, 1 (1990); M. Barinaga, *Science* **249**, 856 (1990).

17 October 1990; accepted 28 January 1991

"I didn't even know there was a union of unconcerned scientists."