would be contingent upon such eye movements. But this interpretation relies on Kohler's (*4*) report of color conditioning that was gaze contingent, and recent attempts (*5*) have failed to replicate his original observations.

In electrophysiological research (*6*) neurons in the visual system of the monkey that respond to moving contours have been described. These motion detectors have preferred directions. Psychophysical experiments (*1*) suggest that similar cells exist in the human visual system. In the present experiments, different populations of motion detectors would respond to ascending and descending motion. It is possible that the motion-detector cells show color adaptation to the wavelengths paired with their preferred direction. After adaptation the cells would remain more sensitive to other wavelengths, and in white test light, these adapted cells would signal a color complementary to the adapting color. This neurophysiological process could underlie observers' reports of negative color aftereffects specific to a particular direction of motion.

In these experiments cumulative, spaced stimulation was used to produce lasting color aftereffects. Such experimental conditions typically result in habituation, the conditioned inhibition of sensory responses (*8*). Persisting color aftereffects which are motion contingent may be the result of this conditioning process (*9*).

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References and Notes

1. C. McCollough, *Science* **149**, 1115 (1965).
2. R. Masland [thesis, McGill University, Montreal, Canada (1968)] found that after 15 minutes of exposure to a rotating spiral, observers reported an aftereffect of seen motion when they returned to view the same spiral 22 hours later. Observation of this persisting motion aftereffect suggested that experience which paired motion and color might also produce a lasting modification of perception.
3. Wratten filters No. 33 (magenta) and 61 (yellow green), Eastman Kodak Co., Rochester, N.Y.
4. I. Kohler, *Sci. Amer.* **206**, 62 (1962).
5. C. McCollough, *Amer. J. Psychol.* **78**, 362 (1965); T. L. Harrington, thesis, University of Oregon, Eugene (1964).
6. D. Hubel and T. Wiesel, *J. Physiol.* **195**, 215 (1968).
7. R. W. Sekuler and L. Ganz, *Science* **139**, 419 (1963); R. W. Sekuler, paper read at meetings of the American Psychological Association (1967).
8. S. Grossman, *Textbook of Physiological Psychology* (Wiley, New York, 1967), p. 641.
9. Recent unpublished observations by C. McCollough, Oberlin College, and C. Stromeyer, Harvard University, confirm the existence of color aftereffects which are motion-contingent and similar to those reported here.
10. Supported by a Canadian National Research Council grant to D. C. Donderi.

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Hypothalamic Motivational Systems: Fixed or Plastic Neural Circuits?

Abstract. *Eating and drinking were elicited by electrical stimulation through the same electrode in the hypothalamus of a satiated rat. Intensity thresholds for eliciting eating and drinking were different, and both thresholds decreased with repeated testing. These findings suggest an alternative to the hypothesis that the neural organization of hypothalamic drive systems is modified by experience.*

In the rat, eating and drinking are mediated by the same general "feeding area" of the lateral hypothalamus. Lesions in this area usually produce both aphagia and adypsia (*1*), and both eating and drinking can be elicited by electrical stimulation in the area (*2*). On the other hand, the relative independence of the neural mechanisms of eating and drinking is shown by the fact that chemical stimulation through a given cannula in the feeding area produces either eating or drinking, depending on the nature of the chemical agent used (whether it is adrenergic or cholinergic) (*3, 4*). Thus, it appears that eating and drinking involve neural drive systems that are interwoven anatomically, but whose functional independence is preserved by chemical coding. While such a view is widely accepted, it has been recently challenged by Valenstein, Cox, and Kakolewski (*5*). They question the existence of fixed and stable neural drive systems, and suggest that the function of hypothalamic drive structures can be modified by experience. I now present data which show that the findings of Valenstein *et al.* do not require such an interpretation.

The proposal of Valenstein *et al.* (*5*) is based on their finding that electrical stimulation of a particular site that initially elicits only one response (for example, eating) can come to elicit a different response (for example, drinking) as a function of experience. In their study, animals with electrodes in the lateral hypothalamic area were electrically stimulated in a cage where food, water, and wooden wedges were available. The intensity of the stimulation was gradually raised until it reliably elicited eating, drinking, or gnawing. Stimulation intensity was fixed at this level, and then the objects appropriate to the observed response were removed (for example, if the response displayed by the animal was eating, food was removed from the cage). Stimulation was then continued on an overnight schedule with only the other two materials present (that is, water or wooden wedges). After several nights of such stimulation, a second stimulation-bound response, appropriate to one of the remaining objects, emerged. When the animal was restimulated in a situation with all three stimulus objects once again present, this second response (gnawing or drinking) was found to be about as likely to occur as the original response (eating). Valenstein *et al.* seem to interpret this finding as evidence that the hypothalamic drive systems are plastic in that the drive-specificity of particular cell populations can be altered by learning.

An alternate hypothesis is that, in experiments involving electrical stimulation of lateral hypothalamic sites, fixed and stable independent drive systems are simultaneously activated, and that stimulation experience merely changes the thresholds of the different systems without altering the functional organization of any. My study was designed to test this hypothesis.

Monopolar electrodes were implanted in the lateral hypothalamus of 23 adult albino rats of the Wistar strain (*6*). The electrodes were stainless steel wires (0.010 inch in diameter) insulated with lacquer and cut off square at the tip. Electrode connectors were imbedded in dental cement anchored to four stainless steel screws in the skull. A skull screw over the olfactory bulb served as an indifferent electrode.

One week after surgery, subjects were screened in preliminary testing for stimulation-bound behavior. Each rat was placed in a box with free access to food and water, and its electrodes were connected with flexible wire leads to an electrical stimulator. The rat was stimulated with 60 hz sine-wave pulses 20 seconds long with a 20-second interval between stimulation periods. Intensity of the stimulation was 5 μa on the first stimulation and was increased slowly until stimulation-bound eating or drinking or an aversive response was observed, or until an intensity of 100 μa was reached. Eight subjects showed stimulation-bound eating or drinking; only these subjects were used in further testing.

Next, intensity thresholds were determined. Each subject was placed in a box

containing only the object it responded to in preliminary testing. Stimulation was administered on a 20-second-on, 20-second-off schedule, beginning at the intensity which elicited a response in preliminary testing. If, on a given trial, no eating or drinking was observed, current intensity was raised in 2-μa steps on subsequent trials until a response was elicited. When a response was observed, stimulation intensity was decreased in 2-μa steps until the response was no longer observed. Threshold was defined as the average of the "on" and "off" intensities thus determined by the animal's behavior on ten trials after an initial stabilization period.

To determine if both eating and drinking systems could be activated by stimulation at the same site, I tested animals that drank in preliminary testing for their eating thresholds in boxes containing only food. Stimulation was begun at the intensity which produced drinking, and was then increased gradually to a range which produced eating; the stimulation was then varied, as in the original threshold determination procedure. Similarly, the original eaters were tested for their drinking thresholds. All five of the animals which drank in preliminary testing also ate when stimulated at a higher intensity with only food available. Similarly, those that originally ate only, drank at higher intensity (Fig. 1). In addition to these subjects, subjects that had had electrodes similarly implanted for other experiments were also tested for eating and drinking thresholds. In all, 55 electrode placements in 43 animals in this laboratory have been carefully screened in this manner, and almost all of them have elicited both eating and drinking when stimuli of appropriate intensities which initially produced only one of these behaviors were given through an electrode (*7*).

Table 1. Stimulation thresholds for nondominant responses elicited by lateral hypothalamic stimulation after 3 nights of stimulation experience. Overnight stimulation intensity (training intensity) was fixed at the level first observed to reliably elicit the dominant response for a given animal. See text for explanation.

Animal (No.)	Threshold before training (μa)	Training intensity (μa)	Threshold after training (μa)
25	15.2	10.0	9.0
30	22.5	8.0	5.1
32	35.0	25.0	22.3
33	28.4	20.0	17.3
37	25.6	18.0	15.7

These results indicate that, for the particular area of the lateral hypothalamus stimulated, electrode placements capable of producing stimulation-bound eating are usually also capable, independent of any significant stimulation experience, of eliciting stimulation-bound drinking, and vice versa. They suggest that in the experiment of Valenstein *et al.* only one type of response was seen initially because stimulation intensity was above threshold for only this response. Had the experimenters systematically examined for the different responses by stimulating at different intensities with only one of the testing objects present at a time, they would almost certainly have found that the sites of their electrode placements could initially mediate more than one response. Thus their experiment provided no legitimate basis for the conclusion that the occurrence of the second response was mediated by neural networks reorganized as a result of the overnight stimulation experience.

To determine the effects of repeated electrically induced eating and drinking on eating or drinking thresholds, I continued testing daily for 10 days. Each session included ten to fifteen trials in which stimulation elicited eating or drinking. In all animals the thresholds for both eating and drinking decreased over the first few days (Fig. 1). By the 6th day the threshold for the nondominant response (the response which had the higher threshold on the 1st day) had decreased to below the intensity which first elicited eating or drinking in preliminary testing. This finding could explain the emergence of a nondominant response after overnight training in the study of Valenstein *et al.*, if such threshold changes could be assumed to occur as a result of experience with stimulation which was subthreshold for the nondominant response, as it was in their study.

To test the validity of such an assumption, I tested five experimentally naive rats for initial eating and drinking thresholds and then gave them overnight experience following the procedure of Valenstein *et al.* Within three overnight sessions all animals exhibited the nondominant response, at the same intensity that first elicited only the dominant response. They were then tested for threshold for the nondominant response. Final intensity thresholds were in all cases lower than both the initial thresholds and the intensity eliciting the dominant response on the first testing day (Table 1).

Thus the emergence of eating in response to electrical stimulation which initially appears to elicit only drinking does not require the assumption of a

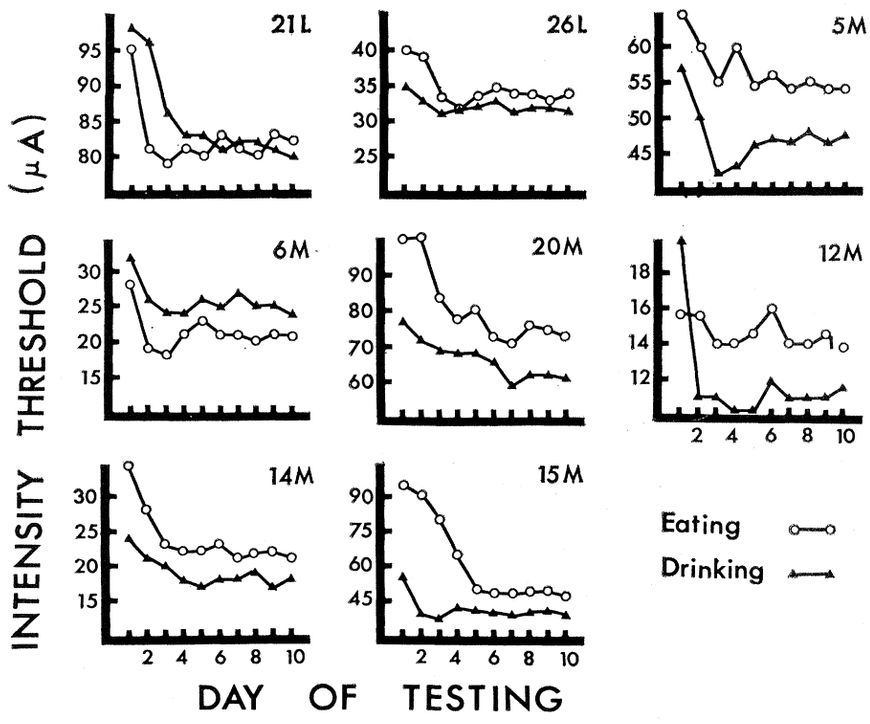

Fig. 1. Daily thresholds for eating and drinking elicited by electrical stimulation of the lateral hypothalamus (eight subjects).

change in the functional organization of the hypothalamic neurons mediating eating or drinking. Rather, this finding is consistent with the theory that separate, fixed neural circuits, functionally isolated from each other by biochemical specificity (*4, 8*), mediate eating and drinking in this area of the brain. Whether the observed threshold changes result from an increase in the sensitivity of the drive systems, or from a decrease in the effects of factors such as fear or curiosity, which may be causing conflicting responses, remains to be investigated.

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References and Notes

1. P. Teitelbaum and E. Stellar, *Science* **120**, 894 (1954); P. Teitelbaum and A. N. Epstein, *Psychol. Rev.* **69**, 74 (1962).
2. J. Mendelson, *Science* **157**, 1077 (1967); E. E. Coons, thesis, Yale University (1964) (microfilm obtainable from University Microfilms, Inc., Ann Arbor, Mich., order 64–13, 166); G. J. Mogenson and J. A. F. Stevenson, *Physiol. Behav.* **1**, 251 (1966); *Exp. Neurol.* **17**, 119 (1967).
3. S. P. Grossman, *Amer. J. Physiol.* **202**, 872 (1962); N. E. Miller, K. S. Gottesman, N. Emery, ibid. **206**, 1384 (1964). For a general review, see N. E. Miller, *Science* **148**, 328 (1965).
4. A. E. Fisher and J. N. Coury, *Science* **138**, 691 (1962).
5. E. S. Valenstein, V. C. Cox, J. W. K. Kakolewski, *ibid.* **159**, 1119 (1968); E. S. Valenstein, paper read at the 39th annual meeting of the Eastern Psychological Association (Washington, D.C., 1968).
6. The stereotaxic coordinates and surgical procedure are the same as described in J. Mendelson, *J. Comp. Physiol. Psychol.* **62**, 341 (1966). The electrode target is just lateral to the descending column of the fornix in the anterior-posterior plane of the ventromedial nucleus. The subjects are being used in further experiments; histological information which is not essential for the present argument will be reported later.
7. Of 55 electrode placements, 45 elicited both eating and drinking, 7 elicited both eating and gnawing, 1 elicited both drinking and gnawing, 1 elicited only eating, and 1 elicited only drinking. Only those placements not eliciting both eating and drinking were tested for gnawing.
8. J. N. Coury, *Science* **156**, 1763 (1967).
9. Supported by PHS grant (MH-03238-07) and National Research Council of Canada grant (APB-74) to Dalbir Bindra. I thank Dr. Bindra for his help.

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Polymeric Bridging Fibrils?

Ries and Meyers (*1*) report that electron-microscope pictures of deposited sols, to which a polymeric cationic agent had been added before deposition, showed polymeric fibrils acting as "bridges" between the colloid particles. The colloids in question were placed on collodion-covered grids by "direct deposition." This, I assume, means that a droplet of sol was placed on the prepared electron microscope grid and then allowed to dry. Measurements of zeta potential in the dilute sol were then correlated with states of agglomeration shown in the electron microscope pictures. When the samples contained high concentrations of polymeric cationic agent, threadlike objects were seen to radiate out from colloid particles and were taken to represent bridging by polymeric fibrils.

I have experimented with similar colloidal systems using both Zeta Meter and electron-microscope techniques. Although similar degrees of flocculation were observed, no threadlike fibrils were found. Because agglomeration is strongly influenced by electrolyte concentration and by zeta potential, both of which would change during a drying of the sol, it was found necessary to literally freeze the dilute sol in its original state. Only in this way were the various effects of concentration during drying, and rafting due to the meniscus, eliminated. Thin films of dilute sol were rapidly frozen on Formvar films supported on glass slides. The ice was sublimed away, leaving the sol particles in their original state of agglomeration.

I suggest that the fibrils illustrated in the report by Ries and Meyers could conceivably be explained by the precipitation of the cationic polymer during drying, the colloid particles quite naturally providing nucleation points for the deposition. It is questionable from the evidence presented that polymeric "bridging" fibrils actually existed in the dilute sol after addition of cationic agent.

That there exists a straightforward correlation between the conditions in a dilute sol and the coagulation evidenced by the electron-microscope pictures of dried films is not clear.

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Reference

1. H. E. Ries, Jr., and B. L. Meyers, *Science* **160**, 1449 (1968).

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We do not claim that there is a "straightforward correlation" between conditions in a dilute sol and the structures observed in the electron microscope. However, our zeta-potential and electron-microscope studies on two model colloidal systems strongly suggest that "charge neutralization and bridging may function simultaneously."

As the Smith-Johannsen statement indicates, electron-microscope investigations of such systems are difficult at best. To observe the fiberlike structures formed by a polymeric flocculant, great care must be exercised, not only in sample preparation but also in shadow-casting and in the electron microscopy proper, particularly at the higher magnifications that reveal a fiber thickness approaching polymer dimensions. In spite of this attention to detail, fibers are not always detected. Freeze-drying has been used for sample preparation in some of our experiments and fiber structures quite similar to those found by other techniques have been observed.

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