terference technique permits one to bypass the effects of optical aberrations and thereby to effectively take advantage of any clear areas remaining in the lens. In addition, the red light from the helium-neon laser is probably scattered less than light of shorter wavelengths is. The above factors permit the principal causes of poor vision, the scattering of light from the cataractous parts of the lens and the poor image-forming properties of the peripheral parts of the eye's optics (*5*), partially to be circumvented.

In any event, in order to produce regular patterns on the retina behind an opaque lens, at least some portion of the coherent light must pass through the lens unscattered. It seems that the denser the cataract, the more difficult it becomes for patients to detect the regular fringes in the disordered pattern produced by the cataract. Particularly if the patient has a dense cataract, failure to see the fringes may not necessarily indicate a lack of potential for good vision.

The results reported here indicate that preoperatively determined interference fringe acuity can be used to assess the potential for visual improvement in a significant number of cataract patients. Furthermore, it seems likely that this test can be used to differentiate between retinal and optical causes of visual loss in a host of other disorders involving the dioptrical apparatus of the eye.

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3. One might think that it is impossible to relate the resolution of such complex patterns as letters to that of gratings in a simple way. However, the literature [for example, Y. Le Grand, *Form and Space Vision* (Indiana Univ. Press, Bloomington, 1968)] indicates that for the normal eye there are only small differences at photopic luminances between grating and letter acuity. Does the generalization that grating and letter acuities are equal (when the acuity is expressed in terms of the angle subtended by the smallest detail) hold for patients with less than normal vision? In an effort to answer this question, letter and fringe acuities were measured on a group of 19 patients (23 eyes) having various degrees of visual loss caused by other than optical factors. These patients had a mean letter acuity of 0.38 and a mean interference fringe acuity of 0.42. The coefficient of correlation between letter and grating acuity was .95.
4. The letter visual acuities were determined by the patient's physician, using suitable lenses to correct for refractive errors. Generally, the postoperative acuity was obtained 3 or more months after surgery when it seemed likely that the eye had achieved its full potential for improvement.
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Circadian Rhythm of Brain Self-Stimulation Behavior

Abstract. *Under constant conditions of light, sound, temperature, and humidity, rats exhibited circadian rhythmicity in rate of bar-pressing with hypothalamic and septal reinforcing brain stimulation. Variations in reinforcer magnitude affected absolute levels of operant response emission but not the frequency of the circadian rhythm. In long sessions, the time of peak responding deviated systematically from a strict 24-hour period. Such data show marked similarity to free-running rhythms of motor activity.*

Oscillation is a temporal property that unites and interrelates biological systems. Studies of behavioral oscillation have concentrated on stabilimetric activity or locomotor response chains. Both of these measures reflect complex and unspecified behavioral repertories, and various subsets of such behavior samples may dominate an activity count at different times. Overall rates of behavior output do not change as much as the relative dominance of particular topographical units (*1*). Isolation and measurement of a narrowly defined, highly probable response unit would likely lead to a more refined analysis of cyclic behavior patterns and their associated physiological oscillation mechanisms. A popular way to insure the high probability of a response is to reinforce it, rather than to rely on its "spontaneous" emission. For our experiments, we selected the relatively stereotyped operant bar-press as the unit for measurement. To maintain responding for long periods, we used brain stimulation as the reinforcer, eliminating (or minimizing) the rapid satiation effects found with traditional nutritive reinforcers. We report a circadian periodicity in operant response rate during long-term self-stimulation sessions, with the use of a variety of stimulation parameters, electrode loci, and reinforcement schedules. The cyclic response patterns show many of the same characteristics as locomotor activity as well as hormonal, neural, and cellular rhythms, and may reflect common biological oscillation mechanisms (*2*).

Male albino laboratory rats (Charles River, CD strain) were implanted with septal or hypothalamic bipolar electrodes (Plastic Products, MS 303), or both, and were allowed to self-stimulate in continuous sessions for as long as 1 month. Placements were verified by subsequent histological analysis. Bar-pressing was reinforced by 0.5-second trains of constant-current bidirectional rectangular pulses, 0.2 msec in duration, equally spaced in time. A single peak-current level and electrode locus were chosen for a given session. The experimental compartment was enclosed in a controlled environment chamber (Sherer-Gillett, CEL 44) with dry food and water continuously available. An incandescent lamp illuminated the chamber, maintaining a constant luminance of 10 ft lam (10.7 mlam) on the wall at the level of the bar. External noise was attenuated by the multilayered enclosure, and temperature was set at 70°F (21°C) with 50 percent relative humidity (*3*).

When an animal starts a self-stimulation session, it usually responds at a high rate without resting. Subsequent deceleration in response rate occurs, but its onset depends on stimulation intensity. At high intensities the initial response spurt may last as long as 2 days without rest periods of more than a few minutes. Only later does the animal periodically slow its responding and take long enough rests to exhibit a circadian rhythm. Initial response deceleration, occurring after about 8 hours of self-stimulation (sometimes thought to parallel a food "satiation" effect) has previously been reported only for septal placements (*4*). We observed the effect for both hypothalamic and septal loci with low and medium stimulation intensities; at high intensities the initial response deceleration was greatly delayed.

Figure 1 includes continuous week-long samples of response output from several animals under a selection of locus, intensity, and schedule conditions. Responses were tallied in 6-hour blocks, and smooth curves were fitted by eye. The records show wide differences in peak rates under the various reinforcement conditions (ranging from approximately 500 to 3700 responses in a 6-hour block), as well as in day-to-day regularity in response output by individual animals. For example, rat X2, in the septal condition under continuous reinforcement (CRF) at 0.10 ma, showed relatively stable oscillations, with peaks generally exceeding 2000 bar-presses, declining to less than 400 bar-presses in quiet periods. By contrast, rat Y3, in the hypothalamic CRF condition at 0.10 ma, showed great daily fluctuations in peak response output (ranging from about 1500 to 3700 bar-presses), with no clear trend across days.

Regardless of the amplitude characteristics of the individual records, these animals all exhibited orderly cycles of high and low rates of bar-pressing, approximating a 24-hour period (*5*). The most orderly records show successive peaks following each other in every fourth 6-hour block, with rest periods symmetrically interspersed. Responses may be intermittently reinforced (see Fig. 1, rat B33) without obscuring the cyclic pattern, and the locus of reinforcing brain stimulation is not critical. Similar records of locomotor activity are often said to reflect an endogenous circadian timing mechanism (*6*).

Our data suggest that learned behaviors, maintained exclusively by the reinforcement contingency (*7*), may be subject to similar temporal control. Many studies of locomotor activity (*6*, *8*) index the time of discrete onset of activity, disregarding amplitude characteristics of the rhythm, although subtle gradations in daily activity output have been noted (*9*). For brain self-stimulation, we find a continual behavior stream with no discrete activity onset, and the analysis concentrates on rhythmic oscillations in amplitude, which parallel measures of physiological variables (*10*).

The rate of response is proportional to reinforcer magnitude, within limits, for both brain stimulation (*11*) and conventional ingested reinforcers (*12*). However, this phenomenon has been demonstrated only in short sessions and has not accounted for daily oscillations in responsiveness. By manipulating stimulation intensity in long-term sessions, we have found that reinforcer magnitude and oscillation factors jointly determine momentary response rate. Results for rat X2 in the hypothalamic CRF condition are plotted as a family of curves in Fig. 2. Four intensities were presented in irregular orders (to minimize possible series effects) for periods ranging from 1 week to 1 month. The uppermost curve represents responding at 0.30 ma—a very high intensity for this animal. Over the 3 days sampled, response totals ranged from about 18,000 to 38,000 in 6-hour blocks, with the distinct circadian pattern also noted for this rat under septal reinforcement (Fig. 1). The curves for lower intensity values indicate proportional declines in the baseline level of response. Aschoff (*13*) has suggested that an important parameter of circadian rhythms is the "level around which the system oscillates," which, in our situation, was controlled by stimulation intensity. The circadian pattern of responding seemed unaffected by changes in response baseline due to reinforcer magnitude. Under all conditions, successive peaks followed each other at about 24-hour intervals.

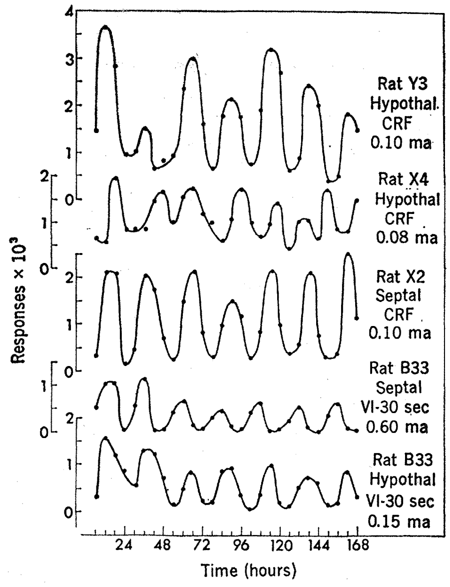

Fig. 1. Week-long response records (6-hour blocks) sampled from continuous sessions of intracranial self-stimulation.

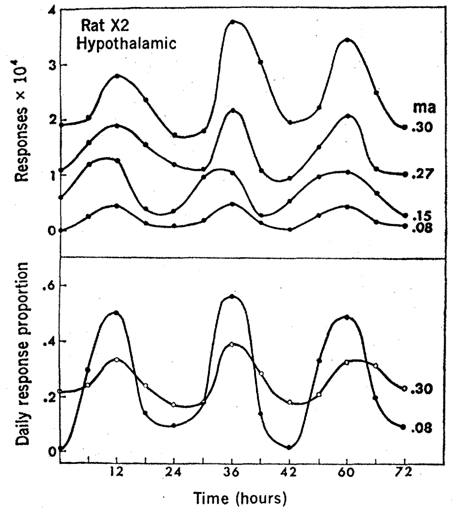

Fig. 2. Three-day samples of response records for rat X2, with various intensities of hypothalamic stimulation. The upper panel shows selected records of total responses (6-hour blocks), and the lower panel plots response proportions for the highest and lowest intensity presented, for successive days. The curves have been superimposed on the abscissa in order to emphasize the similarity in phase characteristics.

The lower panel of Fig. 2 shows a transformation of the absolute response totals for the lowest and highest intensities to a proportional measure, correcting for the amplitude difference. Responding in successive 6-hour blocks is expressed as a proportion of daily (24-hour) response output. Both curves show circadian periodicity, but the oscillation is more pronounced under the condition of low intensity (0.08 ma) stimulation. This effect contrasts with the absolute response records in the upper panel of Fig. 2, which show greater amplitude variation under the condition of high intensity (0.30 ma) stimulation, and thus a more dramatic circadian pattern. When the animal rested in the low-intensity condition, its response rate dropped to nearly zero for extended periods, while in the high-intensity condition it still emitted about 20,000 responses in a 6-hour "quiet" period. The extremely low response levels obtained with low-intensity reinforcement resulted in the more discrete dips and peaks in the response proportion function. However, the rate of temporal oscillation was neither accelerated nor decelerated by changes in reinforcer magnitude or baseline response levels.

One ubiquitous characteristic of free-running circadian rhythms is the consistent small deviation from an exact 24-hour period, in the absence of external pacing stimuli (*13*, *14*). Thus, the time of peak activity is found to shift later when the circadian period exceeds 24 hours, or earlier when the period is less than 24 hours. Since the deviation from 24 hours is small, long sessions are required to demonstrate the peak shift empirically. Figure 3 summarizes such a record for rat X2 in the hypothalamic CRF condition at 0.08 ma. Four curves are superimposed on the abscissa (Eastern Standard Time), with 3-day samples from the month-long session averaged in terms of daily response proportions (correcting for day-to-day

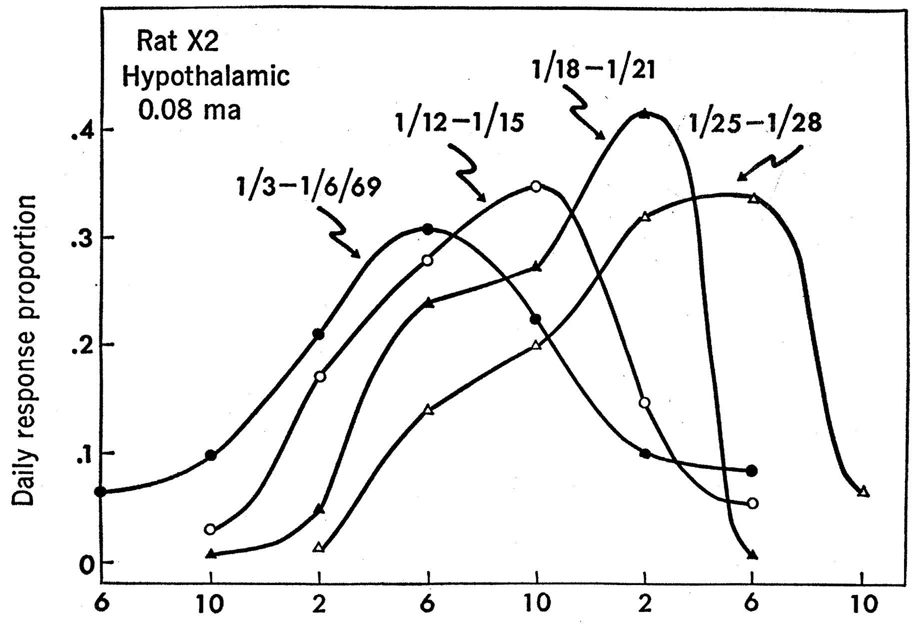

Fig. 3. Averaged daily response proportions (4-hour blocks) for sampled 3-day periods in the course of a month's testing with low-intensity hypothalamic stimulation, for rat X2.

variations in baseline response output). From 3 to 6 January 1969, peak response rate occurred at about 6 p.m.; when the behavior pattern was sampled 1 week later, the peak had shifted to the next 4-hour block, centered at 10 p.m. Subsequent samples revealed a continuing shift to later peak periods, reaching 6 a.m. near the end of January. The transition from peak activity to low activity appeared to become more abrupt as the month progressed. The data show that, on the average, peak response rate occurred about 20 minutes later each day; in 2.5 months, we would predict that the animal would "lose" about one objective day. A computer analysis of these data showed that the least-squares fit to a 24.3-hour trial period yields a ratio of 0.076 between the standard error of the amplitude and the amplitude itself (*15*). Such data support the conclusion that the operant behavior rhythm is not synchronized by an external clock corresponding to the 24-hour day. This result agrees with Aschoff's rule, which predicts that a nocturnal animal in constant light will show a circadian rhythm greater than 24 hours.

The present experiment demonstrates that the technique of intracranial self-stimulation can be profitably used to refine behavioral activity analyses. Indeed, Prescott (*16*) has shown that one index of general activity correlates positively with self-stimulation rate. Perhaps an oscillating temporal factor, related to physiological arousal states (*17*), modulates reinforcement strength. Our self-stimulation records may reflect rhythms in hypothalamic or limbic neural activity. Not only does the hypothalamus mediate strong positive reinforcement effects, but also its control over pituitary secretions (for example, adrenocorticotrophic hormone) is thought to underlie changes in general motor activity (*18*).

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Alcohol Aversion in the Rat: Behavioral Assessment of Noxious Drug Effects

Abstract. *Injections of* p-*chlorophenylalanine or* n-*butyraldoxime given after rats were first given a 10-minute drinking test with saccharin or ethanol solutions produced a learned aversion to these solutions. These findings suggest that the reduced self-selection of alcohol (preference) resulting from the administration of these drugs, reported by others, is not specifically alcohol-related. The technique described offers a sensitive procedure for the assessment of unpleasant effects of drugs.*

There is considerable research interest in drugs which have the effect of reducing the intake of ethanol (*1*), although there is little understanding of the mechanism by which such a reduction occurs. Drugs such as disulfiram or *n*-butyraldoxime (*n*BAO), which are aldehyde dehydrogenase inhibitors, are