A circadian variable in self-exposure to light by the rat¹

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When given control over illumination, a rat changes his light or dark condition with a rate that has a circadian periodicity. In isolation, with temperature and humidity controlled, a gradual and systematic phase shifting occurs that renders periodic, exogenous cues an implausible explanation. A near 24 h periodicity in need for stimulus change is implied by data. No light-dark cycle comparable to the day and night rhythm was obtained.

Determinations of illuminance preference of rats have been made by Lockard (1962, 1963) and by Johnson (1964, 1965). Using bar pressing and locomotor response measures respectively, data obtained by these investigators differ in support of a preference hypothesis (Lockard & Lockard, 1964) suggesting a range of dim illuminations which have greater preference value than darkness. A confounding issue is the reinforcement value of stimulus change which, as Johnson (1965, p. 541) noted, varies in specific relationship to apparatus and procedure used; the effect of the variable of illumination change is apparently reduced with a locomotor response and increased with a bar-press response.

The issue of organismic need for stimulus change is generally related to the theories stemming from sensory deprivation (Brownfield, 1965) and perceptual organization by active involvement (Gibson, 1966). As Sollberger (1965, p. 26) states, the animal in the field as well as man himself "builds his own environment to such an extent that it is truly an extension of himself."

The primary objective was to determine the rat's ability to place himself on a circadian cycle of light and dark. According to Lockard (1963) "It would not be unreasonable to expect self-produced periods of light and dark to bear an orderly relationship to the circadian locomotor periodicity characteristic of many rodents. Were this so, the motivation for bar pressing for light would be associated with the maintenance of a rhythmic system and the light begins to resemble a 'primary need' more than a mere sensory change [p. 522]."

Fig. 1. Illumination durations selected in hourly units. More time in dark than in light for any specific hour is indicated by black rectangle.

Fig. 2. Frequency of change in illumination. Black rectangle > 25 responses; dark gray 17-24 responses; light gray 9-16 responses; and no shading < 9 responses.

Subject. The S was a male hooded rat (four months old) of the Long Evans strain. Prior to this study S was maintained in an individual cage on a constant light schedule of 12 h dark and 12 h light (1-5 ft-c depending on location of meter probe).

Apparatus. The cage housing was a light-tight wooden box (75 x 75 x 87 cm) with 10 W incandescent lamps mounted on the ceiling with a Fresnel lens and a white translucent, vinyl plastic sheet suspended under the lamps as diffusers. A fan and baffled intake and exhaust ports allowed for adequate ventilation. Room temperature (mean = 72 deg F, ± 1 deg F) and humidity (mean = 42.2 deg RH, SD 4.7 deg RH) were controlled and measured intermittently to assure no daily periodicity.

On the floor of the wooden surround and 66 cm under the diffusers a transparent plastic cage (38 x 25 x 15 cm) was fitted with two levers located at opposite ends of the box 5 cm from the floor. Any bar press altered the light (1-2 ft-c) to dark or the reverse by use of a ratchet relay. A capacitive-discharge circuit prevented bar holding artifacts.

A 20 pen event recorder was used as a cumulative counter and a milliammeter recorder was used to detect light alterations within the chamber as sensed by a Delco LDR-25 photoresistive cell installed as one arm of a Wheatstone bridge circuit and located on the floor of the surround next to the cage. The purpose of the milliammeter recording was to facilitate data analysis and furnish continual check on operation of lights, switches and relays.

Procedure. The S was placed in the clear plastic cage on December 5, 1967 and remained until January 28, 1968 (55 days). Food and water were always available and the cage was serviced once every three days at irregular times of day. During the first 44 days S had control of light; on Day 45 and thereafter the light was continuous regardless of bar pressing. Both recorders were maintained in continuous operation throughout.

Results. The light-dark selection pattern was aperiodic (Fig. 1) and appears comparable to that composed from a random numbers table (Holmquist, Retiene, & Lipscomb, 1966, p. 662). During the course of 44 days a free running circadian periodicity in bar press frequency became evident and a positive phase shifting of 24 h is observed when plotted on a 24 h base (Fig. 2). Taking the first hour with 10 or more presses following at least 6 h of less than 10 presses/h the regression of Y (hour of commencement of pressing) on X (days) yielded a line of best fit $y = 3.99 + x (0.64)$ with standard error of estimate for regression of Y on X equal 2.14. The correlation (r) for goodness of fit equals .97. Predicted values for Days 0 and 44 show a positive phase shift of 28.16 h with mean period of 24.6 h. Thus, the rat lost one plus calendar day during the course of 44 days in isolation.

DISCUSSION

It is unlikely that any periodic environmental cue influenced the results (for opposing views see Brown, 1965). Existence of such a cue is remote since it would have to be aperiodic in reference to the 24 h calendar day, the 23 h 56 min sidereal day, or the 24 h 50 min lunar day. In constant light, phase shifting exhibited a considerable positive increase, further evidence against synchrony with some extrinsic rhythm. The argument against synchrony to environmental cues is also supported by the work of Ternes, Farrer, & Deavours (1967) who reported similar results for nutritive reinforcement in the chimpanzee.

Percentage of successive 24 h days spent in light shows an extensive variability (mean=58.0; SD=16.3), a further indication of the relative lack of significance for any precise duration of daily light or dark required.

Bar pressing for stimulus change cannot be attributed to random movement since only 20 and 30 presses occurred on Days one and two, respectively when a high degree of activity would be expected on the basis of response to a novel cage. Also, during Days 45-55 while in constant light, there was a decrease in daily bar pressing of approximately one SD from the mean daily rate of the preceding 10 days. Continued periodicity of response in constant light may be related to auditory self-stimulation from the microswitch click associated with each bar press.

In conclusion, the present data supports an endogenous circadian rhythm in the rat that is reflected in the voluntary behavior of bar pressing for stimulus change. Further work in progress with dark-reared animals offers additional support for this position.

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NOTE

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