

Phase Shifting an Exogenous Variation in Hamster Activity by Uniform Daily Rotation¹ (37737)

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It has been recently pointed out (1) that the explanation of the long intractable biological clock phenomenon probably lies within the domain of interaction between organisms and rhythmic subtle geophysical fields. It was proposed that the rhythmic environmental field provides the well-known essentially temperature and chemical-factor independence of the temporal foundation for the rhythmically recurring, adaptive, genetic and environmentally modified, biological patterns. The patterns, in addition, include a useful feature of phase lability between the organismic and geophysical cycles.

The foregoing hypothesis suggested that associations were effected within the living system between influences of subtle geophysical fluctuations such as the electromagnetic, on the one hand, and fluctuations in such overt ones as light, temperature, sound, and chemical factors, on the other (2). The subtle field variations were postulated not to elicit adaptive responses except as they might perhaps serve as token or predictive "stimuli" for biologically significant environmental events. Overt-factor variations, of course, include numerous ones having direct survival value for organisms.

Many recent studies have disclosed that living systems are extraordinarily responsive to electromagnetic fields of closely the strength of the natural ambient ones (3-6); indeed organisms may display decreasing specific responsivenesses to fields both weaker and stronger. With the natural fluctuations within these fields activity rates of some or-

ganisms have been shown to be able to correlate either positively or negatively, indicating that these organisms have the ability to alter sign of response. Study of bean water uptake has indicated that this sign, whether + or -, may be determined or biased by other very weak ambient electromagnetic parameters, even ones of biological origin (7).

In order to learn more concerning the probable continuous interaction between responses of organisms to covert and overt environmental parameters and to extend our information of this to mammals, spontaneous activity of male hamsters, *Mesocricetus auratus*, on slowly rotating platforms was investigated. It has been previously discovered that for plants significant biological effects resulted from rotation at speeds ranging from 6 rpm to 1 revolution per day (rpd), and that the consequences of clockwise (CW) rotation were not the equivalent of those for counterclockwise (CCW) (7, 8).

Four hamsters, each occupying its own actograph, were equidistantly spaced around the edge of three 4-ft circular platforms. Each actograph recorded independently on a Esterline-Angus events recorder. The data were quantified by dividing each hourly interval into 10 equal units and indicating within how many of these units any activity was noted. A single incandescent light source for each platform, providing about 2 fc illumination at the hamsters' locations, was programmed on a 12:12 light-dark schedule with light on at 6 AM and off at 6 PM in order to retain light-synchronized 24-hr activity patterns for all animals and thus avoid "free-running" cycles whose mechanism of

¹ This research was supported by Grant No. GB-31040 from the National Science Foundation.

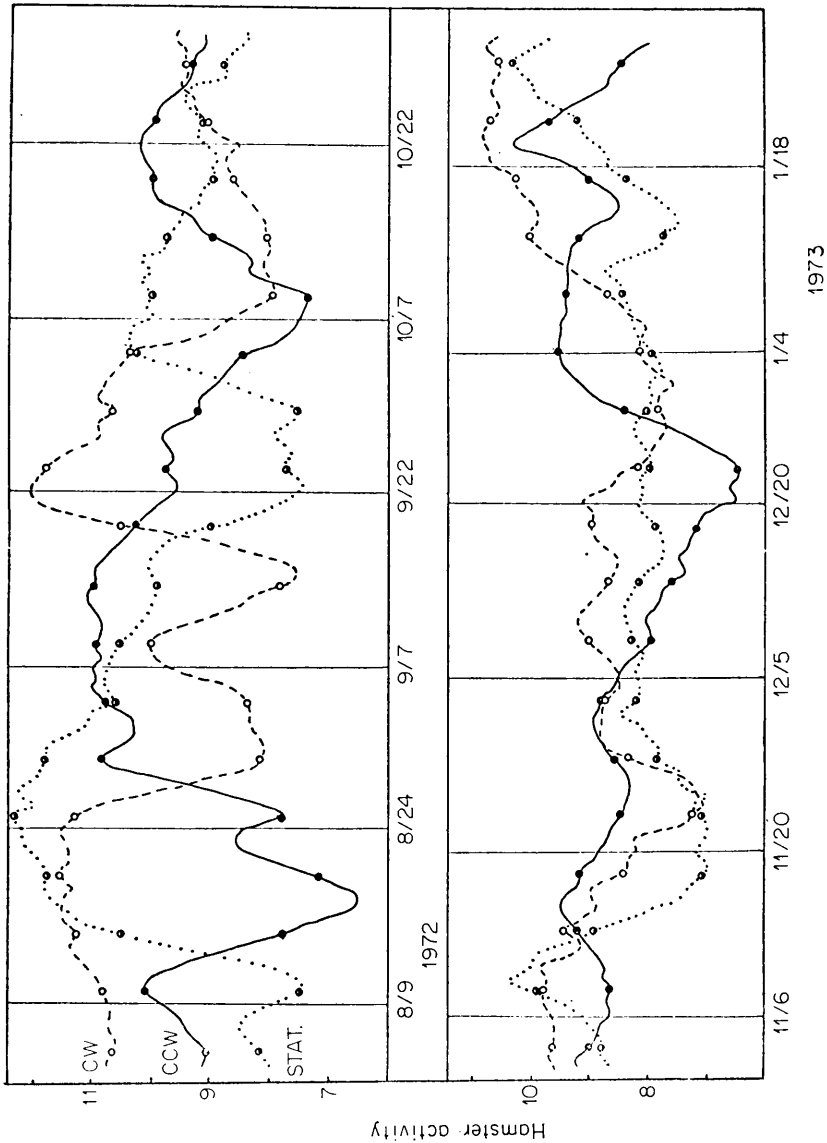


FIG. 1. Five-day moving means of spontaneous activity in 12:12 light-dark (light, 6 AM to 6 PM) for three 4-hamster groups. One group was on a CW-rotating platform (1 rpd), the second was on a CCW-rotating one, and the third, the control group, occupied a fully equivalent but nonrotating platform. Ordinate values are mean hourly values $\times 4$.

period determination remains controversial (1). The lights were 18 in. above the platform centers. One platform remained stationary, another rotated 1 rpd CCW (viewed from above), and the third one, 1 rpd CW. The experiment commenced on Aug. 1, 1972 and continued through Jan. 31, 1973. The hamsters in their actographs were moved to

a different platform every 2 wk in the arbitrary sequential order, stationary-CCW-CW-stationary . . . All hamsters contributed, therefore, to the results from each of the three platforms to compensate for individual differences. Several animals that died during the experimental period were immediately replaced by new ones.

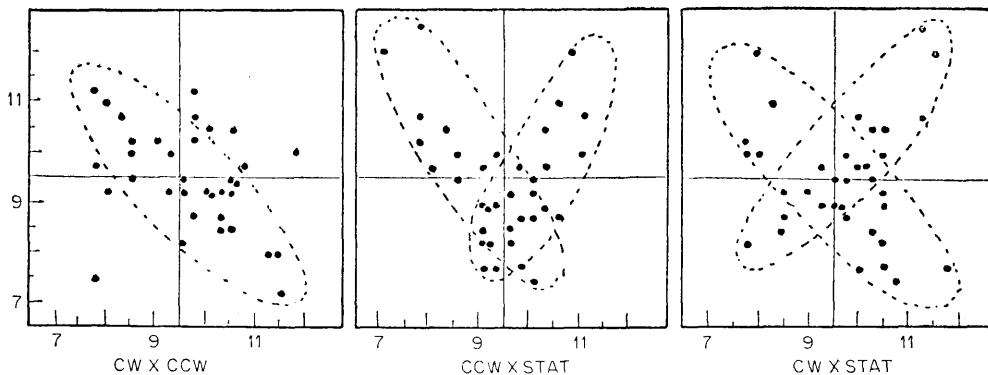


FIG. 2. Scatterplots between the concurrent, separate 5-day means among the three experimental combinations of conditions, *i.e.*, CW, CCW, and stationary platforms. For all values for the interval Nov. 16 through Dec. 31, 1972, 1.5 activity units was added to each and every value. Broken lines envelop oppositely correlating populations of values.

For all hamsters there was produced by the rotation of the platforms a steadily and systematically altering relationship between all perceived overt parameters of their environment such as those involving photic and tactile receptors and their fluctuating environment of subtle factors. The systematically changing relationships were in opposite directions for the two rotating tables. When the animals were on the stationary platform the overt parameters, on the contrary, provided a relatively stable frame of reference for the fluctuating subtle-field parameters of the atmosphere. For all three platforms the light program contributed a 24-hr period. For both rotating tables there was an additional source of 24-hr periodicity, namely the rotational period of the tables. Organisms have been demonstrated to possess a geographical directional sense independent of all obvious clues (3-5). For the CCW platform the artificial "sun" would have for the hamsters an apparent directional motion appropriate for the northern hemisphere and for the CW table the apparent motion would be in the opposite direction.

Results of the 6-mo continuous investigation are illustrated in Fig. 1. This includes the pooled data for the four hamsters from each table, stationary, CW, and CCW, separately. Two groups, stationary and CCW, occupied the same room and were separated only by an opaque partial screen, preventing one group from seeing the other, or its light

source. The CW table was in another, but overtly fully equivalent, room closeby. To disclose the trends about which the individual-day data were varying, a 5-day moving mean was employed. There is adequate evidence (9, 10) that the individual-day means reflect importantly responses to day-to-day weather-system-correlated fluctuations in pervasive factors. These last were not the focus of concern of the present investigation. And greatly reduced would be any quarterly lunar fluctuational element, a period which may prove to be widespread (11).

Brief inspection of Fig. 1 discloses for the individual platforms systematic variations involving consecutive 5-day spans and that these systematic changes over any given interval are commonly in opposite directions for two different platforms. The fluctuations in spontaneous activity for the CCW-rotating hamsters appeared to display a particularly consistent negative correlation with those for the CW-rotating ones.

Figure 2 depicts scatterplots of the relationships between the 36 separate 5-day means among the three hamster groups, all three combinations, which were obtained over the whole 6-mo study. Since all values from all three platforms dropped to a lower mean level for the interval from the middle of November through the end of December, for purposes of the scatterplots 1.5 was arbitrarily added to every value for this period. This treatment would not be expected to in-

fluence the relative variations among the values for the three platforms, the concern of this analysis. For the relationship, CW \times CCW, the values confirm a negative correlation. Emphasizing the predominantly negative relationship between these two experimental conditions, exclusion of outlying values by any of three means (a) not considering the 3 values below 7.25 or above 11.75, (b) arbitrary exclusion of the single very widely isolated value, or (c) omission of the two points conspicuously discontinuous with the general population, strengthens very greatly the evident negatively correlating relationships.

For comparable relationships of CCW \times stationary and CW \times stationary there are clearly no comparable suggestions of a simple correlation, yet some real dependencies between them are evident from the V and X relationships apparent in the scatterplots. For the CW \times stationary, there is clearly sug-

gested an approximately 50-50 distribution of positive and negative correlating values. For the CCW \times stationary relationship, for larger values of CCW there is indicated a positive correlation between them and for smaller values, a negative one.

It should be emphasized that these 180° phase differences did not involve the large-amplitude circadian activity cycles; these latter remained period-synchronized with the 12:12 light-dark schedule and appropriately phase-related for hamsters' nocturnal habit (see Table I), obviously continuing to hold this frequency even while being transferred among experimental tables with their synchronized light programs. Involved instead was a form and/or amplitude modulation of the cycles. It may be reasonably assumed that these activity variations over the 6-mo period of the investigation described influences on the hamsters of subtle exogenous fluctuations. There is, interestingly and suggestively, a broad minimum for all platforms centered over the winter solstice. On such an assumption it seems apparent that the signs of the correlating response to at least one major fluctuating environmental parameter for the hamsters under the two differing experimental conditions, CCW and CW, are predominantly the opposite of one another. The range of these negatively correlating variations over the course of the study is great. Differences even for a single, concurrent 5-day interval apparently ascribable to the oppositely correlating signs show a range (6.4-11.5) up to nearly 80% increase from the group with lower activity to that of the group with the higher.

One is led to conclude, therefore, that hamsters, as has been earlier discovered for water uptake by bean seeds (7), are potentially able to display either + or - states, the two states reflected in opposite signs of correlation with a subtle, pervasive atmospheric parameter whose fluctuations are capable of eliciting quite substantial alterations in animal motor activity. Relative to the stationary, both the CW and CCW rotations produce a random sign distribution. However, CCW and CW, for any given time and environment, tend significantly to be correlated

TABLE I.

Hr (CST)	Mean hourly activity ($\times 4$) Aug. thru Jan.		
	Static	CCW	CW
1	12.12	11.94	13.75
2	10.29	10.76	10.82
3	9.22	10.50	10.72
4	9.17	10.35	10.65
5	9.28	8.89	10.27
6	5.02	6.40	6.02
7	2.68	3.09	3.24
8	1.93	1.94	2.11
9	2.84	2.87	2.67
10	2.60	2.91	3.18
11	2.75	2.38	2.70
12	2.37	2.38	2.18
13	2.63	2.39	2.70
14	2.72	2.39	2.72
15	3.04	2.79	3.22
16	3.30	3.25	3.65
17	4.30	4.74	4.74
18	9.00	8.66	9.03
19	19.44	18.88	18.40
20	26.93	26.37	27.09
21	24.26	23.45	23.11
22	19.69	18.58	19.60
23	16.44	15.23	17.23
24	13.60	14.19	15.70

with opposite signs. Such ranges in spontaneous activity in terms of differing energy demands or stress for the individuals which are concerned indicates the far from insignificant nature of not only the effects of subtle, pervasive geophysical factors themselves but also of the effects of whatever the additional conditions are that serve as the sign-determining ones. Such substantial rate-differences suggest potential clinical applications of the phenomenon were it to become better understood and capable of being manipulated at will.

Too little descriptive information concerning the phenomenon and its properties is available to enable fruitful speculation upon the cause or physiological basis of the sign changes in response to the relevant atmospheric factors. However, the CCW-CW difference indicates it not to be simply the 24-hr periodicity of the rotation effecting a 180° difference in geographic orientation of the light for the hamsters between light-on and light-off since rotation CCW appears to be responsible for the opposite sign of correlating response to that for CW. Also, other conditions than rotation appear capable of determining sign alteration in a living system. For water uptake in bean seeds a fully comparable 180° phase shift involving essentially the same percentage rate-ranges has been described for a 2 mo study between concurrent experiments performed inside and just outside a metal-sheathed temperature-controlled chamber, under what have previously been presumed to be fully equivalent experimental conditions (7). Opposite signs may also occur through biological-field interactions between two groups of beans in separate vessels a few centimeters apart (7). Whether in the present investigation any comparable field interaction between the two symmetrical 4-hamster groups on the CCW and stationary platforms only 1 ft apart contributed to those oppositely correlating signs between the stationary and CCW hamsters at time of relatively low activity of the latter can not be resolved on the basis of the

present experiments.

It is evident, however, from all experimental results to date that the sign determination is susceptible to experimental manipulation in the laboratory, and hence it should be possible ultimately to identify the specific effective parameters for the organisms. That the rotational influences are in some simple, direct manner related to the period of the earth's rotation seems presently contraindicated. The study by Jones (8) was performed in the southern hemisphere (New Zealand); CCW rotation at 1 rpd stimulated, and CW rotation depressed plant growth. The same directional differences have been obtained also for plant growth, in brief, unpublished repetitions of Jones' phenomenon in our laboratory in the northern hemisphere. Clear differences also occur between CW and CCW rotation at far more rapid rates, at least up to 6 rpm (7). Conceivably the differences could result from something as fundamental as interaction with the geoelectromagnetic fields during rotation of optically asymmetrical chemical compounds contributing to protoplasmic structure.

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Received June 12, 1973. P.S.E.B.M., 1974, Vol. 145.