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Magnetic Induction of a Circadian Cycle in Hamsters

by

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ABSTRACT

Locomotor activity in hamsters, *Mesocricetus auratus.* in 24-h LD cycles with light from 06.00 to 18.00 h, and simultaneously in imposed 26-h weak magnetic cycles (ranges varying from 0.260 to 0.008 gauss), significantly reflected both periods. A 24-h circadian pattern (ca. 200% of mean) was modulated by a concurrent 26-h circadian pattern (range ca. 14% of mean).

INTRODUCTION

An organismic responsiveness to extremely weak magnetic fields has now become widely established (Becker, 1974, 1975; Bennett and Huguenin, 1969; Brown, 1962; Brown et al., 1960a; Brown 1960b; Lindauer and Martin, 1968; Palmer, 1963; Stutz, 1971; Wehner and Labhart, 1970; Walcott and Green, 1974; Wiltschko and Wiltschko, 1972). These fields have been proposed to contribute not only directional information for animal homing and navigation but also to provide periods for biological clocks that underly the abundantly described solar- and lunar-correlated biological rhythms. Recent reports have suggested that imposed weak magnetic cycles can entrain circadian rhythms in beans (McBride and Comer, 1975), mice (Gribble, 1975) and birds (Bliss and Heppner, 1976). Indeed, a phase-response complex to geomagnetism for hamsters has been described through investigations of the effects upon them of clockwise and counter-clockwise rotation (Brown and Chow, 1976). This complex includes the major environmental periods, the solar and lunar day, the month and year, and implies that a measurable amount of hamster activity is steadily entrained to these natural atmospheric periodisms. The present investigation attempted to disclose whether a non-geo-

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physical period in a weak magnetic field could impose a synchronized period on hamsters (*Mesocricetus auratus*).

METHODS

The experiments were performed in two small windowless rooms. In both rooms a 24-h lighting schedule, LD 12:12, with light onset at 6:00 CST was maintained. Light was produced by a cluster of four 6-W lamps. In one room a 26-h cycle, 14:12, in the vertical magnetic vector was imposed, and in the other, the same cycle in the horizontal vector. The magnetic cycles were produced by altering current flowing through 106 turns of #24 copper magnet wire on cardboard cylinders 50 cm in diameter and 30 cm high. A lower current strength was present for 14 h and a higher one for 12 h. The cylinders were oriented to augment either the natural vertical or horizontal terrestrial vectors. Each hamster occupied its own rocking-cage actograph constructed of 0.64 cm galvanized iron screening, a material which would alter very slightly the natural and experimental magnetic fields. Activity was registered on an Esterline-Angus events recorder. Each actograph was centered inside a vertical or horizontal coil. The four coils in each room were arranged in an approximate square. The north and south pairs were alternately energized with 26-h cycling current strengths, effecting lower-amplitude (inverted for the vertical coils) cycles in the non-energized coils (N-EC). The experiment was performed twice, once between May and October, 1976, in which the pairs were alternated at 10-day intervals, and a second time between October, 1976 and January, 1977, with the alternation at 13-day intervals. Small changes in the distance between coils were made between the two experiments.

The hamster data were quantified as hourly values indicating the number of tenths of the hour containing any activity. These values were tabulated before knowledge of the concurrent magnetic fields. The magnetic strength changes, independently recorded, became known and super-imposed over the data only later.

The controls comprised data from the same number (4) of control animals from an earlier study in the same rooms over the same durations but when no 26-h cycles were present.

RESULTS

The data were searched for any significant mean 24-h and 26-h patterns which might be present. The mean pattern which was obtained from superimposing all the 24-h cycles during each of the two experimental series is shown in Fig. 1. The hamsters received not only the 24-h light cycles but also the subtle atmospheric 24-h ones. The form is that of a typical entrained hamster circadian cycle, with range about 200% of the mean.

For the first experiment the numbers of complete 26-h hamster "days" which were available for superimposition after deletion of transitional days or other incomplete ones were 230 for the vertical EC fields and 229 for the N-EC ones. For the horizontal EC fields there were 204 days and for the N-EC, 196.

For the second experiment, every hour of six full sweeps of the 26-h cycles by the 24-h ones for the vertical coils were employed as were every hour of five full sweeps by the 24-h ones for the horizontal ones. This gave 144 26-h "days" for the vertical and 120 for the horizontal coils. The results of the eight experimental

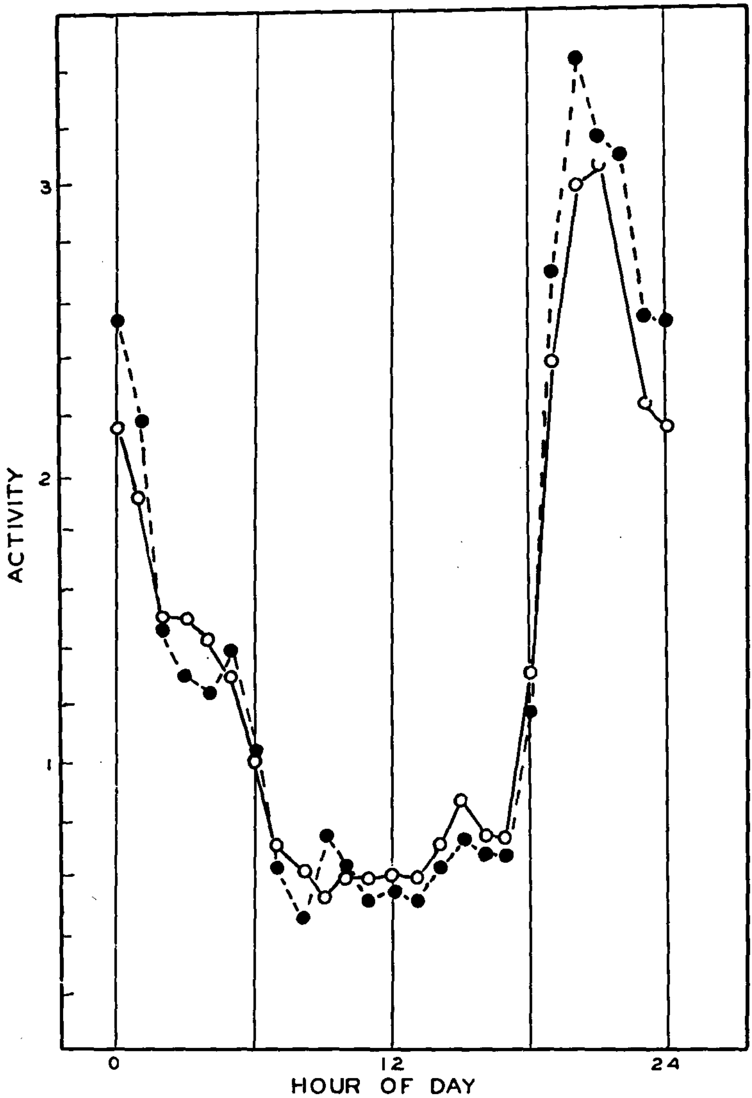

Fig. 1. The mean 24-h patterns of activity in eight hamsters while steadily subjected to 26-h magnetic cycles during the first experiment (solid line) and the second one (broken line). The animals were in LD 12:12 cycles with light onset at 6:00 h CST.

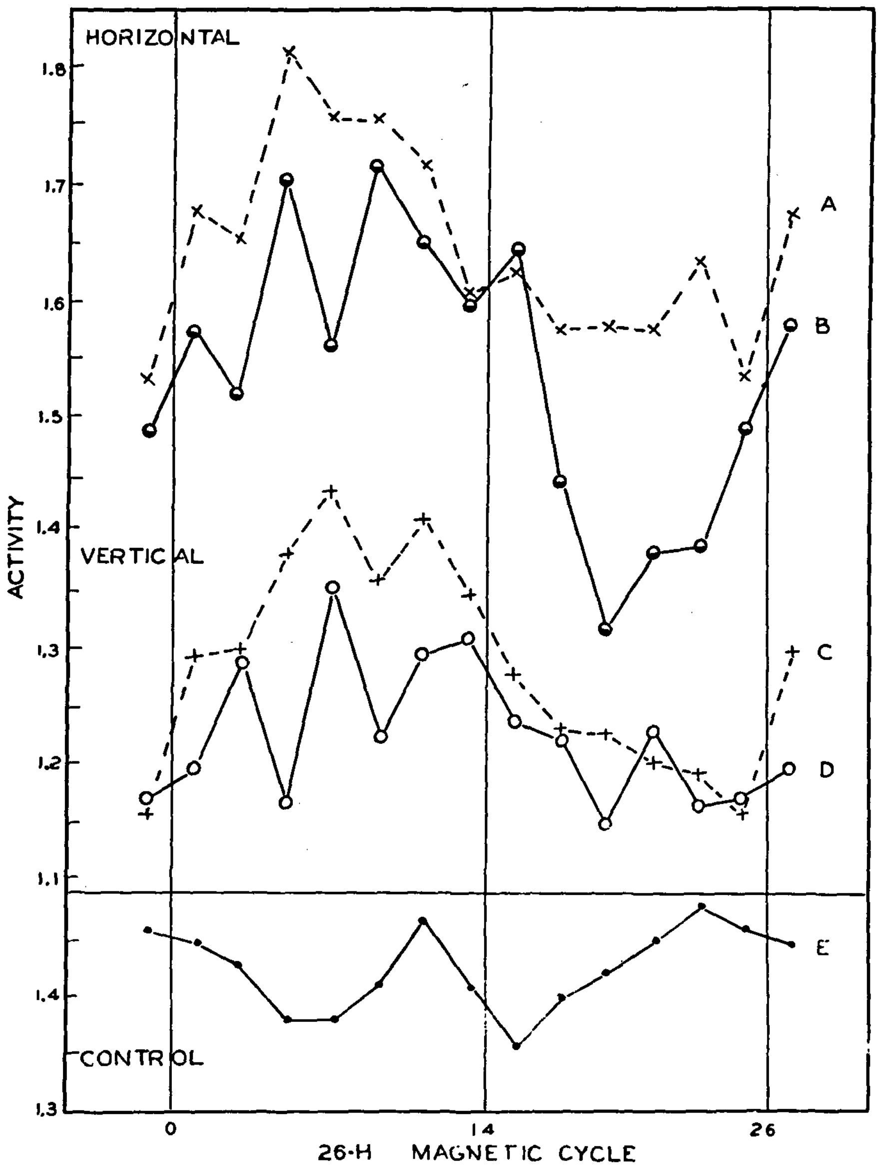

Fig. 2. The mean 26-h patterns in hamsters subjected to square-wave 26-h (14:12 h) magnetic cycles including two orientations and eight ranges. The four upper plots are averages of the two experiments which gave similar results. A. Weaker (N-EC) horizontal cycles. B. Stronger (EC) horizontal cycles. C. Weaker (N-EC) vertical cycles with field strengths reversed. D. Stronger (EC) vertical cycles. The imposed experimental magnetic fields were modified very slightly but complexly inside the ferric-screen actographs just as are normally the geomagnetic ones. E. Controls, with no 26-h environmental cycles.

series, plus controls, are included in Table 1. Field strengths and cyclic ranges are also included.

The averaged results for the two experiments are outlined in Fig. 2 for each of the four conditions separately along with the comparable controls. The values are 2-h means to parallel the 2-h daily phase shifts of the magnetic cycles relative to the 24-h LD ones. The mean magnetic field strengths are all close to the weak natural terrestrial ones.

For every one of the eight conditions over the two experiments the activity was different between the two portions of the magnetic cycles, with the directional differences as depicted in Fig. 2. The significances, by t-tests, yielded $P<0.02$ for the averaged vertical EC field and $P<0.001$ for each of the averaged remaining three fields. No significant difference within 26-h cycles was noted between fully equivalent 14 and 12 hour components for the controls.

The overall levels of activity of the four hamsters in the horizontally and vertically cycling fields differed significantly from one another as is evident from Fig. 2. It is assumed that this difference reflects the influence of the orientation of the pasteboard cylinders, enabling somewhat more illumination from the lights above to reach the animals in the vertical fields than those in the horizontal during the lighted portions of the cycles.

DISCUSSION

Whereas activity was greater at lower field levels within the cycles for both horizontal mean strengths, the reverse was true for the N-EC vertical field cycle. The EC vertical, the strongest, and which qualitatively acted like the horizontal, gave the lowest mean value for the difference, suggesting the cycle to be near a point of sign reversal in magnetic response. Supporting this suggestion was the fact that the magnetic effect gradually decreased with decreasing strength of the horizontal magnetic fields (from EC to N-EC) while for the vertical ones with the higher strength and cycle range (EC) initially having a smaller effect than did both horizontal fields, the hamsters' response changed sign as the cycle decreased in strength and range. A change in sign of response to experimental magnetic fields with strength has been described for planarian orientation (Brown, 1962). Reversals in sign, or flip-flops, of response to an unidentified atmospheric factor have been reported also for a variety of animals and plants from cross-correlations with correlates of meteorological parameters (Brown, 1958a, 1960, 1962), from observed forms of geophysically-correlated solar and lunar biological cycles (Brown, 1960, 1973), and from concurrent cycles of primary cosmic-rays and organisms (Brown et al., 1958).

It is important to note that the square-wave magnetic cycles did not impose a similarly formed cycle on the hamsters (Fig. 3). Instead the 26-h hamster cycle was suggestively a regular, almost sinusoidal, pattern with maxima and minima occurring symmetrically 8-10 h following a field-strength change. Any quick response to magnetic change was of minor nature compared to the cyclic effect of the field. This characteristic of a circadian response to magnetism is postulated to reflect a genetic organization for the organism permitting synchronization to an environmental circadian frequency (Brown, 1969, 1976). It is significant that the amplitudes of the hamster cycles which are entrained to these weak magnetic cycles are all closely similar to those of mean geophysically-correlated cycles that have been often reported (Brown, 1959, 1960, 1962, 1969). These results indi-

Table 1. The mean activity for thirteen 2-h periods in a 26-h cycle in Magnetic field strength

			Lower field							*Higher field*		
Horizontal EC fields:												
Exp. 1						0.360 gauss ±0.110*						
1.466	1.458	1.500	1.571	1.684	1.728	1.429	1.485	1.385	1.233	1.230	1.350	1.380
					mean =	1.548					mean =	1.344
Exp. 2						0.380 gauss ±0.080*						
1.685	1.573	1.901	1.547	1.747	1.569	1.754	1.802	1.504	1.392	1.534	1.418	1.599
					mean =	1.689					mean =	1.542
Horizontal N-EC fields:												
Exp. 1						0.150 gauss ±0.004*						
1.408	1.411	1.403	1.620	1.526	1.663	1.393	1.426	1.393	1.349	1.436	1.459	1.411
					mean =	1.489					mean =	1.412
Exp. 2						0.200 gauss ±0.007*						
1.942	1.893	2.223	1.897	1.991	1.768	1.817	1.826	1.754	1.804	1.714	1.813	1.652
					mean =	1.933					mean =	1.761
Vertical EC fields:												
Exp. 1						0.700 gauss ±0.130*						
1.332	1.378	1.312	1.491	1.353	1.394	1.620	1.326	1.300	1.317	1.362	1.267	1.274
					mean =	1.411					mean =	1.308
Exp. 2						0.630 gauss ±0.110*						
1.056	1.188	1.012	1.204	1.088	1.192	0.988	1.148	1.148	0.980	1.096	1.052	1.060
					mean =	1.104					mean =	1.080

			Higher field						*Lower field*			
Vertical N-EC fields:												
Exp. 1						0.420 gauss ±0.014*						
1.220	1.273	1.365	1.412	1.338	1.549	1.531	1.336	1.358	1.450	1.353	1.203	1.146
					mean =	1.384					mean =	1.308
Exp. 2						0.400 gauss ±0.004*						
1.372	1.314	1.395	1.457	1.376	1.275	1.163	1.221	1.101	0.996	1.031	1.171	1.159
					mean =	1.336					mean =	1.113
						CONTROLS						
Exp. 1 (5.5 months)												
1.374	1.385	1.374	1.322	1.386	1.344	1.346	1.244	1.388	1.387	1.376	1.356	1.382
					mean =	1.362					mean =	1.356
Exp. 2 (3 months)												
1.510	1.460	1.380	1.430	1.430	1.590	1.470	1.460	1.410	1.450	1.520	1.600	1.530
					mean =	1.467					mean =	1.495

*Mean field, and cycle range

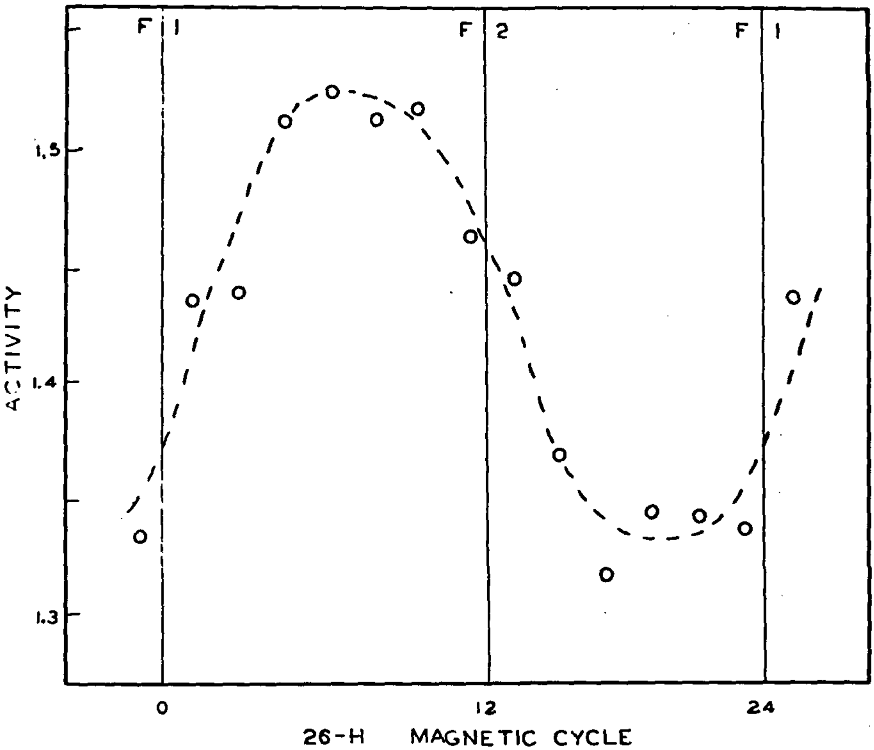

Fig. 3. The pooled results of the eight experiments on magnetic induction of a 26-h cycle in hamsters. The eight magnetic cycle-amplitudes ranged from 0-26 to 0.008 gauss. The hamster activity-range was 13.6% of the mean. F1 and F2 mark onsets of the two magnetic field strengths in the 26-h cycles.

cate that a magnetically imposed mean circadian period of one frequency can coexist with a light-entrained circadian period with a different frequency. The concurrent existence of a 24-h and the 26-h periodicity is interpreted to be consistent with the hypothesis of precise exogenous timing for biological clocks, with "free-running" involving an autophasing phenomenon (Brown, 1972). Accurate clock cycles can coexist with phase-labile, and environmentally imposed, phase-shifting of rhythms.

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