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UNPUBLISHED PRELIMINARY DATA

The rat's anticipation of diurnal and a-diurnal feeding[1]

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Abstract

Ss were trained to press a bar for food and then confined for 21 days to boxes where they could press at any time but where food was obtained only at regularly scheduled feeding times. Different groups were scheduled to eat on diurnal, i.e., 24-hr., cycles or on a-diurnal, 19 or 29 hr., cycles. The a-diurnal Ss were also born, reared and tested under 19 or 29 hr. environmental conditions to provide further stimulus support for the anticipation of feeding. Noneless, they failed to show any genuine temporal discrimination or anticipation of feeding. The fact that the diurnal Ss showed a large, clear anticipation effect indicates that when such an effect occurs it is governed by some sort of 24-hr. biological clock rather than being based upon d eprivation-produced stimuli. Author

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The rat's anticipation of diurnal and a-diurnal feeding[1]

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If rats are fed regularly once a day they soon come to show behavior indicating the anticipation of feeding. For example, in activity wheels there is a marked increase in running in the hours immediately preceding the regular feeding (Richter, 1922; Shirley, 1928). Similarly, consummatory behavior has been found to have greater strength at a regularly scheduled feeding than at other times (Baker, 1955; Bousfield & Elliott, 1934; Lawrence & Mason, 1955). Birch, Burnstein and Clark (1958) have reported that there is a sharp increase in the frequency of contacts with a food trough as the hour approached at which it was regularly filled with food. In more clearly instrumental situations, too, performance has been found to be maximal when it is tested at the accustomed time of day of testing (Birch et al., 1958; Bolles, 1961).

Thus, for a number of different sorts of behavior we have a consistent pattern of maximum motivation at the regular feeding time, and a gradient of increasing motivation, i.e., anticipation of feeding, in the hours just before feeding. The criterion behavior, whether it be consummatory or instrumental or just general activity, may be assumed to be at least in part conditioned to stimuli that recur regularly at the time of feeding. We are not concerned here so much with the mechanisms involved, e.g., whether r_g should be invoked, as with the

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identity of the stimuli to which the anticipation of feeding becomes conditioned. Sheffield and Campbell (1954) have shown that the rat comes to be highly responsive to external stimulus changes that signal feeding, so that any external stimulus changes that are correlated with the time of day may be assumed to gain some control over the anticipation of feeding. However some of the studies cited above have been conducted in relatively constant environments, so some other source of stimulation would seem to be required.

Brown and Belloni (1963), among a number of other writers, have emphasized the potential role of internal stimuli correlated with S's drive state, so-called drive stimuli. Presumably the stimuli arising from a particular physiological state, such as 24 hrs. of food deprivation, are discriminately different from those arising from other states. The anticipation of feeding then becomes a consequence of imperfect discrimination between the particular drive stimuli regularly present at the time of feeding and the similar stimuli that arise at slightly shorter deprivation times. The difficulty with this interpretation is that it is based on research with diurnal, i.e., 24-hr., feeding cycles which confound whatever drive stimulus changes there may be with all of the other diurnal stimulus changes. We cannot tell if S anticipates feeding because it is almost as hungry as it usually is at meal time or because the time of day for feeding is almost at hand.

Bolles and de Lorge (1962) maintained Ss in activity wheels either on diurnal (24 hr.) or a-diurnal (19 hr. or 29 hr.) feeding cycles and found that only the diurnal Ss showed a clear anticipation effect. The activity of a-diurnal Ss tended to follow the available 24-hr. cues rather than their feeding cycle; they would run when it became dark regardless of how soon they were scheduled to eat. This finding suggests that drive stimuli are less important than diurnal stimulus changes in the anticipation effect. However, the presence of 24-hr. environmental cues in the Bolles and de Lorge study may have made this too stringent a test. In the present study a-diurnal Ss lived in a compatible a-diurnal environment so that environmental conditions would support rather than conflict with deprivation time cues. The question then is whether rats can anticipate a-diurnal feeding if they are maintained and fed while isolated from the normal 24 hr. world.

Method

Subjects

Results are presented on 24 male albino rats, Sprague-Dawley strain, approximately 100 days old.

Apparatus

The Ss were tested four at a time in four student demonstration type Skinner boxes. The boxes were in picnic chests which were mounted on rubber in a heavy wooden frame in a specially constructed isolation room. This room had double walls of plywood and acoustic tile, was heavily carpeted, and was located in a small free-standing building. With the exhaust fan running, human observers in the isolation room can hear nothing outside except the low frequency component of loud noises. The rat probably cannot hear sounds of the low frequency which enter, and is, in addition, provided with another 20 db. of isolation by the picnic chest. The lights both in the isolation room and in the Skinner boxes were automatically timed to be on 9.5, 12, or 14.5 hrs. and off a like period. Temperature in the boxes varied between about 75° and 85° each day, warming when the lights were on and cooling when they were off. Temperature in the isolation room varied between 75° and 80°.

Procedure

The a-diurnal Ss were born and reared in the a-diurnal environment in which they were to be tested, and lived in the isolation room until they were old enough to be tested. The 29-hr. Ss occupied the isolation room for about 3 months, then two groups of them were run. Then two groups of 24-hr. Ss were run, and, finally, two groups of 19-hr. Ss were run after they had been in the room for 3 months. The diurnal Ss were obtained from a local supplier and lived in a normal diurnal laboratory situation for two weeks prior to testing.

All Ss were deprived for an irregular period of time between 48 and 72 hrs., put in a Skinner box and trained to press the bar for food. (This was the only time at which the a-diurnal Ss left the isolation room and were not in their accustomed a-diurnal environment.) At this time, which was generally close to the time at which it was to be regularly fed, S was allowed to press until satiated in the experimental situation in which it was to be tested. S was then confined to its box for the duration of the experiment. The experiment lasted 21 feeding cycles during which time the bar was always present and all responses were recorded, but only responses made during the scheduled feeding time resulted in food (45-mg. Noyes pellets). For half of the Ss in each group of four food was scheduled for the middle of the night, and for the other half it was scheduled for the middle of the day. The feeding period lasted 1.9 hrs. for the 19-hr. Ss, and, correspondingly, 2.4 hrs. and 2.9 hrs. for the other two groups, and started 3.8, 4.8, and 5.8 hrs. respectively, after the lights changed. Ss were checked and their supplies replenished generally during a feeding period, after Ss had started pressing.

It should be emphasized that in the present situation S had no cue to indicate the start of a feeding period; without some anticipatory or generalized responding S would miss its feeding. It is noteworthy that this never happened, and that the rate of responding was generally high enough that there was never much danger of a meal being missed except in the case of the first test meal. Upon this occasion S was given about 1 hr. to start responding and if it did not E would then deliver several "free" pellets. Only one S failed to start responding then and it was replaced. All Ss had returned to within 5% of their pre-test ad lib. weight by the end of testing.

Results and Discussion

The data were analyzed in terms of a rather unusual response measure, viz., the number of 4-min. intervals each hour in which at least some responding occurred. The relationship between this measure of the probability of responding and the more familiar raw number of responses during each hour is shown in Fig. 1. Fig. 1, which presents the results for a single typical S during the non-feeding hours in a 5-day experimental period, indicates that there is a high but non-linear correlation between the two measures. The 4-min. interval measure is more sensitive to differences between low rates of responding and increasing less sensitive to differences between higher rates of responding.

Fig. 2 gives the main findings, the probability of anticipatory or generalized responding as a function of time before feeding for Ss fed diurnally every 24 hrs., or fed a-diurnally every 19 or 29 hrs. Each data point represents the mean over the 8 Ss in each g roup of the mean performance over the last five cycles. Since feeding time changes 5 hrs. a day for the a-diurnal S, feeding time over a block of five cycles is almost evenly distributed over a 24 hr. period and a block of five cycles also distributes whatever diurnal effects there may be over the feeding cycle. The 24-hr. Ss show a very high probability of responding in the hr. just before feeding and a fast-rising gradient of responding indicating good temporal discrimination. By contrast, both groups of a-diurnal Ss showed a gradually rising probability of responding and a relatively low probability of responding just before feeding. The difference in probability of responding at the time the feeding period starts is not adequately represented in Fig. 2. However, it was possible to determine directly from the records how long after food was made available that the first response occurred. The mean interval, averaged over the last 5 days, was .38 min. for the 24-hr. Ss and 4.1 min. for the a-diurnal Ss.

Within each group, Ss fed at night behaved somewhat differently from Ss fed in the middle of the day. Fig. 3 shows the results of night-fed and day fed Ss separately. Other things being equal, all Ss respond more in the dark than in the light. The a-diurnal night-fed Ss evidently wait for the lights to go off and then proceed to respond at a fairly high rate; they show little temporal discrimination after the lights go off and before food becomes available. The 24 hr. Ss, on the other hand refrain from responding to the change in illumination for at least one hour, and then respond at an increasing rate as the time for feeding approaches. The a-diurnal day-fed Ss show essentially no discrimination during the day, but the 29-hr. Ss show a gradual increase in responding during the last hours of the night. It is interesting to note that the lights change for the 29 hr. Ss about 24 hrs. after their last feeding, and they behave as though they were anticipating this event at 24 hrs. rather than the feeding which follows 5 hrs. later. Thus it does not seem that any of the groups of a-diurnal Ss were making a true temporal discrimination. Rather, they seemed to be responding to illumination changes, to 24-hr. cues of some sort, or to still more generalized cues in the environment. By contrast, the 24 hr. day-fed Ss refrain from responding for almost three hrs. after the lights go on before beginning to anticipate feeding.

The temporal discrimination improved gradually and continuously over the course of the testing. The probability of responding of night-fed Ss during the day and of day-fed Ss during the night dropped by a factor of about two for the 24 hr. Ss and increased by a factor of about two in the 19 hr. and 29 hr. groups over the 21 days of testing. However, at no time, not even on the first test day, did the discrimination performance of the diurnal Ss look as poor as the best performance of the a-diurnal Ss.

We cannot say on the basis of these results that rats are unable to anticipate a-diurnal feeding, but we can say that such a phenomenon would have to involve a temporal discrimination which is very difficult for rats to make. Moreover, it now seems certain that the stimuli which control the anticipation of diurnal feeding, which the rat learns quite readily, are not those arising specifically from its physiological condition, or drive state - - they are not "drive stimuli" in any real sense. The stimuli that make it easy for the rat to anticipate feeding every 24 hrs. seem to be inexorably bound up with the 24-hr. cyclicity, as though they were being generated by a biological clock. The rat fed every 24 hrs. seems to anticipate feeding not because it is almost as hungry as it usually is at meal time, and not because the time of day for feeding is almost at hand, but primarily because it has not eaten for 24 hrs.

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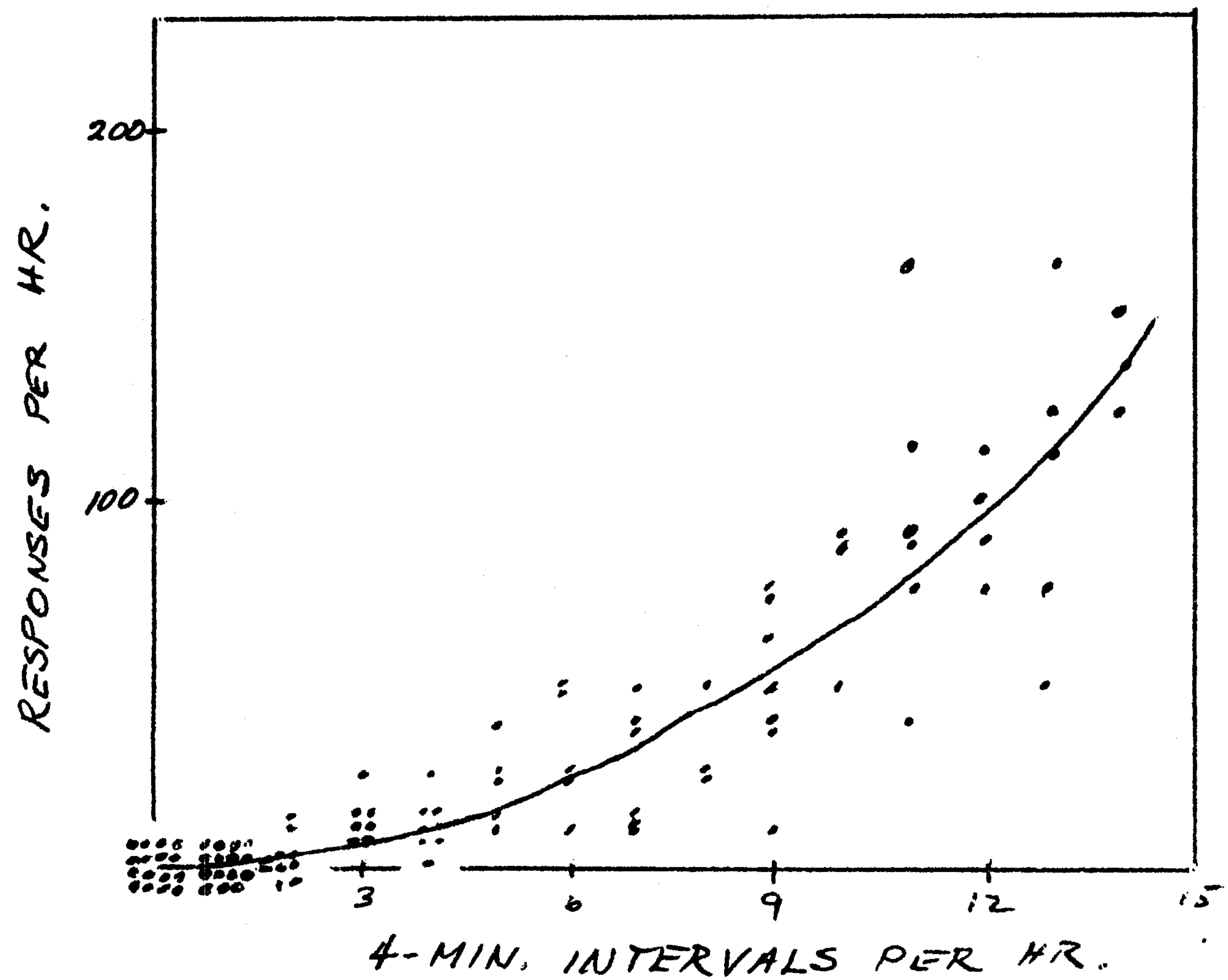

Fig. 1. Correlation between total number of responses per hr. and the number of 4-min. intervals per hr. in which responses occur for a typical S.

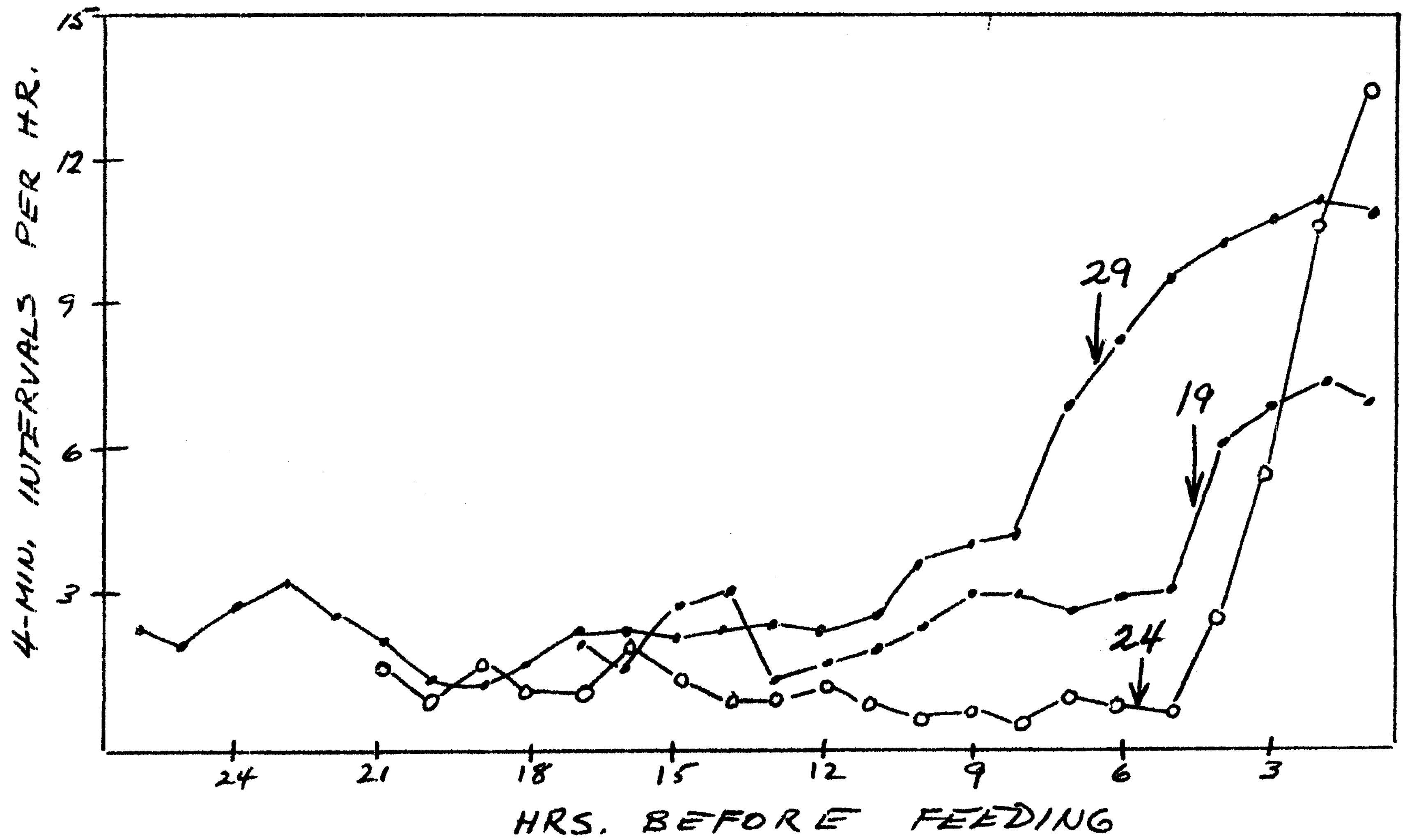

Fig. 2. The number of 4-min. intervals per hr. in which responses occur as a function of time before feeding for Ss fed every 19, 24, or 29 hrs.

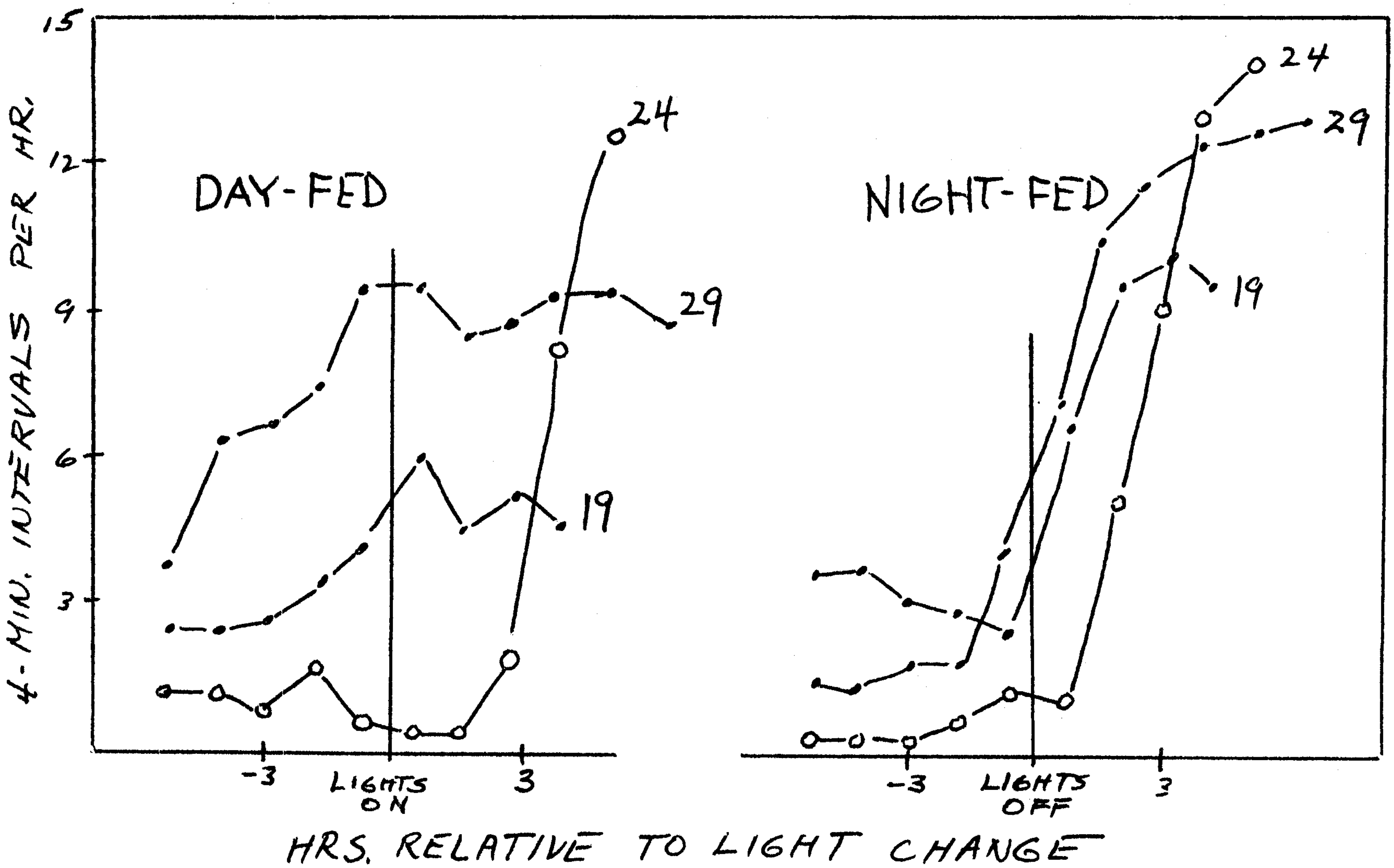

Fig. 3. The number of 4-min. intervals per fr. in which responses occur as a function of time relative to the change in illumination preceding feeding.