ACTIVITY RHYTHMS AND POSITION PREFERENCES OF DOMESTIC CHICKS WHICH CAN SEE A MOVING OBJECT

By D. M. BROOM
Department of Zoology, University of Reading, Reading RG6 2AJ

Abstract. The activity levels of isolated domestic chicks in home pens maintained at constant light and temperature were monitored for 4-6 days after hatching. The data were analysed using correlograms, spectrograms and multiple regression. Most chicks showed 24 h periodicities and also shorter periodicities of 1.5-4 h and about 30 min, but there was considerable individual variation. The importance of short-term rhythms in studies of responsiveness is emphasized. Chicks which could see a small, rotating ball from their home pens were more active than those which could not see a moving object and spent more time near it. The more pronounced 24 h periodicities, shown when a moving object could be seen, were partly due to greater activity, especially that near the object.

Short-term activity periodicities are often overlooked but they may be very important factors in studies where responsiveness is assessed or where precise descriptions of behavioural sequences are required. They are less easy to detect than circadian rhythms of animal activity, whose importance as variables in experimental procedures is often emphasized, e.g. Rusak & Zucker (1975). Statistical methods for detecting more than one periodicity in a series of observations are now readily available to those studying behaviour (Broom 1979) and short-term behavioural rhythms have been described for several species (e.g. Guymar's 1975; Slater 1975). In the experiments reported here, the periodic activities, with wavelengths of 10 min-2 days, of young chicks are described and those of chicks in two different rearing conditions are compared. The rearing conditions used were two of those used by Broom (1968, 1969) and were expected to produce two activity levels. Chicks reared with a moving object were more active than those in grey pens when watched between 0900 and 1300 hours (Broom 1968) although this might have been due to a difference in phase of activity rhythms.

The moving object visible in one of the rearing conditions in this study was similar to those found by Smith (1962) and others to elicit approach by young chicks. Such moving objects probably have an effect on visual detection mechanisms similar to those caused by the flashing or rotating lights used by James (1959) or Bateson & Reese (1969). The experiment provided an opportunity to assess the preferences of chicks for the moving objects, temperature and food by recording where the chick spent time and where it was active. A continuous record of the position of the chick in its home pen was therefore kept.

Methods

The subjects in both experiments were Ross I chicks which had been incubated and hatched in darkness in a Glevum Superior incubator. Within 6 h of hatching six chicks were transferred in a covered box to pens with floor 25 × 30 cm and walls 25 cm high (Fig. 1). The front of the pen was made of 1 cm² Weldmesh whilst the other walls were all made of hardboard painted matt grey (grey pen condition—G) or one wall was transparent Perspex through which a moving object could be seen (moving object condition—O). There were four experimental birds and two extra birds which were placed in the end compartments so that every experimental chick had another chick behind the grey wall on one side of its pen and either (O) a transparent Perspex wall or (G) a grey wall separating it from the continuously moving object. The experimental chicks were two males (one G, one O) and two females. Each O chick was thus matched with a G chick of the same sex and age in an adjacent pen so Wilcoxon matched pairs tests were used on the behavioural data. All P values quoted are two-tailed.

Chick-crumb food and water were continuously available in containers which refilled when the level dropped. Infra-red heaters positioned over adjacent pens (Fig. 1) maintained a temperature gradient of 30-35 C in each pen. An auxiliary heater in the room maintained the room temperature at 26 ± 1.5 C.

The moving object was a ball of white cotton-wool 5 cm in diameter which was mounted on the spindle of a motor so that, when it rotated
once every 2 s, the outer edge described an arc 12 cm in diameter. The electric motor made a faint noise and was mounted behind a 9 × 15 cm piece of grey painted hardboard.

In front of the Weldmesh wall of the pens was a transparent, grey plastic film (Cinemoid) which was angled and illuminated so that it was a one-way screen. An observer could see the chicks but no chick ever saw an observer during the experiment. The pens were continuously illuminated throughout the experiment with a fluorescent strip-light. The room was underground and was never entered by anyone except the experimenter, who checked the chicks twice per day as silently as possible. The sounds of activity in other parts of the building were audible during working hours but were not loud since precautions were taken to minimize sound transmission to the room.

The floor of the pens was divided into six independent Weldmesh sections, each of which rested on a microswitch. The microswitches were modified so that they did not make a clicking noise and so that contact was made when a chick was on the floor section. Each switch on each of the floor sections of the four experimental animals was connected to an Edgcumbe moving paper event-recorder so that the position of the chick was recorded at all times. An electrical circuit was designed which resulted in a count by an electromagnetic counter whenever a chick moved from any floor section to any other floor section.

**Experiment 1**

Four batches of four experimental chicks were kept in the pens for 6 days. During this time their position in the pen was continuously recorded and their activity count was sampled at 30 min intervals. Data on position preferences were obtained from these four batches and from one other batch whose activity counts were not recorded. Data on total activity counts after 1 or 4 days were also obtained from matched pairs of chicks from five other batches.

**Experiment 2**

Four batches of four experimental chicks were kept in the pens for 4–5 days and their activity count sampled at 5 min intervals. Five other batches provided total activity counts after 1 or 4 days for some matched pairs of chicks. No data from any chick was used if it, or the other chick in its matched pair, died before the end of the experiment.

**Activity Rhythm Analysis**

The methods of analysis have been described and compared with other methods (Broom 1979). The terms used are discussed and defined here because of their varied usage elsewhere. The most precise terms are period, periodic and periodicity which are used and defined in a consistent way in the literature of statistics (Bartlett 1966; Hannan 1970; Anderson 1971), economics (Chow 1975), meteorology (Huschke 1959) and most of biology (Harker 1964; Aschoff et al. 1965; Mills 1973). A period is the interval between two events repeated in time; periodic refers to repeated events in a time series which are separated by equal periods; a periodicity is a periodic variation within a time series. As Parzen (1962) points out, a periodic process is a specialized form of a Markov process. The word rhythm is obviously avoided in most of the statistically orientated literature and as Harker mentions, whilst periodicity implies exact regularity in the occurrence of events, rhythm does not. Aschoff et al. and Mills refrain from defining the word rhythm but

---

Fig. 1. Plan of four experimental and two extra pens. All walls were 25 cm high and there was a one-way viewing screen so that the chicks could be observed through the Weldmesh wall. The modified microswitches were fixed under the Weldmesh floor (sections A–F) and were connected to the activity counting circuits and the event recorder.
Aschoff et al. equate it with oscillation in their definition of 'free running rhythm'. Sollberger (1965) states that rhythm implies regularity but uses the term for any alternation of two states. The lack of precision in the meaning of the word is usually overcome by the use of qualifiers such as regular, diurnal or circadian. A useful definition is: *rhythm*—a series of events repeated in time at intervals whose distribution is an approximation to regularity rather than random. The term periodicity should be used instead of rhythm if regularity has been demonstrated by measurement.

Another term which is extensively used in biological, meteorological and economics literature is cycle. Chow (1975) says that a cycle is a repeated function (mathematical). A modification of Huschke's (1959) definition seems generally applicable: *cycle*—a recurrent set of changes such that the state at the end point is the same as that at the start point. This term is useful where there are several changes, as in a reproductive cycle, all of which are repeated. It would include periodic fluctuations, such as a sine wave, but its usage for non-regular sequences of events is so widespread that a definition requiring regularity would be inappropriate. Other terms used in this paper include: *correlogram*—a plot of autocorrelation coefficients against increasing lag, and *spectrogram*—a plot of spectral estimates (Fourier cosine transforms of the autocorrelation function) for successive wavelengths using a given maximum lag.

The range of periodicities which can be detected is limited by the sampling interval, so when it became apparent that chicks might have important short-term rhythms which were not detectable with a 30 min interval, experiment 2 was carried out using a 5 min interval. The correlograms calculated from the time series of activity-counts are for lags of < n/2 as advised by Vandenbussche (1969) and others. Spectrograms were obtained for at least three maximum lags and all the peaks mentioned in the results section appeared on each of these. Where n = 284, lags of 24, 48 and 96 were used and where n = 1364, lags of 96, 288 and 576 were used. The $\chi^2/n$ test was used for the dominant peak on spectrograms and as a good estimate of probability for subsidiary peaks, as explained in Broom (1979) and World Meteorological Association (1966). Other examples of such spectral analysis are the studies of Campbell & Shipp (1974) and Williamson (1975). Dominant 24 h periodicities and trends were removed from the data by multiple regression analysis in order that subsidiary rhythms could be detected and tested statistically by spectral analysis of the residuals, a development of the approach of Chatfield & Pepper (1971). All of these analytical techniques were tested with model data. Correlograms and spectrograms showed the predicted peaks when artificially produced sine waves were analysed and, as in the actual data, multiple regression could be used to remove such a sine wave. Random data produced no large peaks in either correlogram or spectrogram and the number of peaks which reached the $P < 0.05$ and $P < 0.01$ level by the $\chi^2/n$ test were 5% and 0.6% respectively.

**Results**

The results of (1) below, refer to experiment 1. Other results are for both experiments unless they are stated to refer to samples of activity levels taken at 30 min intervals (experiment 1) or 5 min intervals (experiment 2).

(1) **Position in the Pen**

Chicks which could see the moving object (O) spent more time during their first six days in the half of the pen nearer to the object (sections A, B and C) than did chicks in pens whose walls were all grey (G) ($P = 0.005$). The G chicks showed a clear preference for the side which was nearest to the sound of the chick in the adjacent cage and which also included the food container (median 78% of time on D, E, or F; range 53–89%; A + B + C vs. D + E + F $P < 0.01$). This preference was counteracted in the O chicks by the presence of the moving object (median 56% of time on A, B, or C; range 37–89%; A + B + C vs. D + E + F $P > 0.05$). The median times spent on each of the six sections during six days are shown in Table I. The amount of time spent on sections C and F, which were nearest to the heater, was much less than on sections A and D at the back of the pen for both O ($P < 0.01$) and G ($P < 0.01$) chicks. Chicks which did rest under the heater soon panted and moved away.

The time spent on the six pen sections on each of the first six days is shown in Fig. 2. There were no clear changes with age amongst O chicks. The G chicks initially spent almost all of their time on section D but they spent more time on A, E and B after the first two days. On days 1 and 2, G chicks were much more likely than O chicks to be on section D and less likely to be on
section B. They were on A less frequently at all ages.

(2) Activity Levels

The activity counters operated up to 24 h of age for 31 pairs of active chicks and up to 96 h for 28 pairs. As shown in Table II, the median activity rate was higher for O chicks at both ages. There was no clear change with age in the overall activity level, the level at 96 h being higher than that at 24 h in 56% of O birds and 56% of G birds. There was no significant activity difference between males and females but the median male activity level was 15% higher amongst O chicks and 9% higher amongst G chicks. Of the 34 G chicks, none had an activity count of 300+ per day, none died and only three were obviously undersized at four days, but of 34 O chicks, 10 had an activity count of 300+ per day, two died and nine others were weak or obviously undersized at four days. Although 31 G and 23 O chicks were full sized and healthy, the size and survival likelihood of some O chicks was reduced (11/34 vs. 3/34, \( P = 0.028 \), two-tailed Fisher exact probability test). The majority of the chicks which were weak or undersized were more active during the first four days than were other O chicks but some chicks were very active but not weak or undersized. Some of the undersized chicks appeared normal in their movements and healthy.

As shown in Fig. 3, O chicks were 'very active' much more frequently than G chicks on days 1 to 4. When the chicks were watched, the O chicks were often seen running up and down in front of the moving object. When O chicks were

Fig. 2. The percentage of 30 min periods on the six floor sections (A–F) during each of six days. The moving object was nearest to section B. Each point is the median of 10 O chicks (which could see the moving object) or 10 G chicks (which could not). Changes with age: O all \( P > 0.05 \); G section A, day 1 v 3** 4* 5** 6**; day 2 v 5* 6**; G section B, day 1 v 4* 5* 6**; day 2 v 6*; G section D, day 1 v 2** 3* 4** 5** 6**; G section E, day 1 v 4**. (* \( P < 0.05 \), ** \( P < 0.01 \).

| Table I. Median % of Time Spent during 6 Days on Each Floor Section by Chicks Which Could (O) or Could Not (G) See the Moving Object. (Table arranged as in pen—see Fig. 1) |
|---|---|---|---|
| | Food | Water |
| | G 54% \( P = 0.02 \) | O 29% |
| Sound of chick | D | |
| G 14% \( P = 0.02 \) | O 8% |
| | E | A |
| G 3% \( P < 0.1 \) | O 4% |
| Moving object (visible to O only) | G 5% \( P < 0.1 \) | O 15% |
| | B |
| G 3% \( P > 0.1 \) | O 4% |
| Heaters | C |
Table II. Median Activity Rate of Chicks (Counts per Hour)

<table>
<thead>
<tr>
<th>Age (h)</th>
<th>n</th>
<th>O chicks</th>
<th>G chicks</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>31</td>
<td>240</td>
<td>171</td>
<td>0.04</td>
</tr>
<tr>
<td>96</td>
<td>28</td>
<td>277</td>
<td>157</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

'very active' they were more likely to stop their activity bout on sections A or B than were G chicks (P < 0.01) whose few 'very active' bouts usually ended on D. G chicks rested much more than O chicks on day 1 (Fig. 4), but not after this, and section D was a more frequent resting site for G chicks than for O chicks (P < 0.01). On day 1 resting accounted for 31% of the time that G chicks were on D but only 8% of the time that O chicks were on D. The proportion of the time on a section that resting occurred was twice as much on B as on A or D for G chicks and twice as much on D as on A or B for G chicks.

Activity Rhythms

(1) General description. When the number of activity counts in successive 30 min intervals was plotted against time it was immediately apparent that all chicks were rhythmic in their activity. It appeared that most birds, in both rearing conditions, showed a regular rhythm with a wavelength of about 24 h. An example of an activity plot is shown in Fig. 5. The peak level of activity was between 1200 and 2400 hours for 67% of chicks and between 0000 and 1200 hours for 33% of chicks.

(2) Autocorrelation. Visual analysis of activity level plots did not allow adequate comparison of the rhythms shown by G and O chicks and gave little statistically reliable information about the existence of 24 h or shorter wavelength periodicities. Autocorrelation of the data confirmed that most birds showed a periodicity of wavelength of 24 h (Fig. 6). As shown in Table III, most of the 32 birds had peak autocorrelations close to 24 and 48 h and troughs close to 12 and 36 h. Anomalous results include four birds with clear periodicities of wavelength about 12 h and one bird with no clear periodicity above 2 h. It appeared that subsidiary short-term rhythms might be superimposed on some of the long-term rhythms visible from the correlograms. This was checked using spectral analysis and multiple regression analysis as described in the Methods section and by Broom (1979).

(3) Spectrograms. Spectrograms of the data from all 32 chicks also showed that most (84%) had a clear dominant periodicity of wavelength 24 h (χ²/ν test for 27/32 birds, P < 0.001). The five birds which had no clear 24 h periodicity also had no clear 24 h peak on their correlograms. Their dominant periodicities were at 16 h (P < 0.001), 16 h (P < 0.01), 14 h (P < 0.01), 10.5 h (P < 0.01), and 1.7 h (P < 0.001). The existence of periodicities with wavelengths of a few hours or, in the data collected at 5 min intervals, 15–40 min was apparent from the

Fig. 3. The percentage of 30 min periods during each of six days during which the chicks were very active (i.e. changed floor section more than 20 times in 30 min). Each point is the median of 10 G (solid line) or O (dashed line) chicks. Changes with age: G, P > 0.05; O, first three days v. second three days P = 0.01 (symbols as Fig. 2).

Fig. 4. The percentage of 30 min periods during each of six days which included at least five minutes resting. Each point is the median of 10 G (solid line) or O (dashed line) chicks. Changes with age: O chicks, all P > 0.05; G chicks, day 1 v. 2* 3** 4** 5** 6** (symbols as Fig. 2).
spectrograms, but in order to be certain of their existence, and to compare chicks in the two rearing conditions, it was necessary to remove overall trends and the 24 h periodicity from the data (e.g. Fig. 7). The results after doing this are summarized in Table IV and the distribution of all clear \((P < 0.001)\) periodicities is shown in Table V. For the 5 min data, the spectral analysis

![Graph showing activity levels of a visually isolated chick during the 4.7 days after hatching.](image)

**Fig. 5.** The activity levels of a visually isolated chick during the 4.7 days after hatching. Each point is the number of times that the chick crossed from any one of six floor sections to any other during six successive 5 min periods.

![Graph showing autocorrelation plot (correlogram) of chick activity data sampled at 5 min intervals.](image)

**Fig. 6.** Autocorrelation plot (correlogram) of chick activity data sampled at 5 min intervals and summarized in Fig. 5. Autocorrelation coefficients are plotted for all lags from 5 min to 2 days.

<table>
<thead>
<tr>
<th>Table III. Results of Autocorrelation Analysis of Activity Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median time of max. autocorrelation coefficient between 6 and 36 h: 24.5 h (median coef. 0.18)</td>
</tr>
<tr>
<td>Median time of max. autocorrelation coefficient between 36 and 60 h: 50.75 h (median coef. 0.18)</td>
</tr>
<tr>
<td>Birds showing rise in autocorrelation coefficient between 12 and 24 h: ((n = 32)) 78%</td>
</tr>
<tr>
<td>Birds showing drop in autocorrelation coefficient between 24 and 36 h: ((n = 32)) 81%</td>
</tr>
<tr>
<td>Birds showing rise in autocorrelation coefficient between 36 and 48 h: ((n = 16)) 81%</td>
</tr>
</tbody>
</table>
technique cannot detect periodicities of wavelength < 10 min or those just longer than this unless they are very clear. Despite this fact, 13 out of 16 chicks whose activity was sampled at 5 min intervals showed periodicities of wavelength 25–39 min for which $P < 0.05$. Most chicks (75%) had a dominant 24 h periodicity in activity and subsidiary periodicities of 1–4 h and 25–39 min. A few had dominant periodicities of 10–16 h (12%) or subsidiary periodicities of 4–8 h (9%) and one bird had no clear long-term rhythm but a dominant 1.7 h periodicity.

When a record of activity, after removal of trends and 24 h cycle, was broken up into four sections with a brief break between sections and each section was analysed, the spectrograms showed some peaks present in several or all of the sections but others which were slightly different for each section. In the spectrogram of the whole activity record, all of these peaks could be seen but those which had been present in all sections were the largest. Some chicks showed several adjacent peaks, e.g. 2.0, 2.1 and 1.8 h, in their long lag spectrograms. These periodicities are likely to have been shown at different times and may represent minor variations in the operation of some mechanism which controls the patterning of activity. Such minor variations can appear as one peak in a spectrogram for which the lag is short.

4) Multiple Regression Analysis. Multiple regressions against (a) time, (b) a sine wave of wavelength 24 h, (c) a step function of wavelength 24 h, (d) interactions of time and the sine wave, (e) the previous activity count and (f) the activity count before the last showed that each of these factors could be important in helping to explain the variation in the data. Most chicks showed some gradual increase or decrease in activity during the recording period and such trends in the data were shown by the contribution of the 'time' factor in the regression analysis. The occurrence of such trends did not appear to be related to the rearing condition or to the presence of any rhythm. Regression against the 24 h sine wave reduced the total sum of squares most in those individuals where the correlogram and the spectrogram showed

![Graph](image)

Fig. 7. (A) The five highest peaks from the spectrogram (maximum lag 48 h) of the data in Fig. 5 are shown expressed as a multiple of the mean spectral estimate, S(K), in the spectrogram. (B) The four highest peaks and the 24 h point from the residuals of the above data after removal of trends and 24 h sine and square waves by multiple regression.

<p>| Table IV. Wavelengths of Dominant Periodicities in Chick Activity Data as Determined by Spectral Analysis Before and After Removal of 24 h Periodicity and Trends by Multiple Regression (M.R.) |
|-------------------------------------------------|-------------------------------------------------|
| Sample duration | Dominant periodicity before M.R. | Dominant periodicity after M.R. |</p>
<table>
<thead>
<tr>
<th>n</th>
<th>30 min</th>
<th>5 min</th>
<th>30 min</th>
<th>5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 h</td>
<td>13</td>
<td>14</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10–16 h</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4–8 h</td>
<td>1</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>1.5–4 h</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>&lt; 1.5 h</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>
that there was a clear 24 h periodicity. The 24 h step function was seldom an important factor, i.e. it usually did not reduce the total sum of squares by much when included in the regression equation. In 28/32 chicks the 24 h sine wave was more important than the step function and all four of the other chicks showed weak or absent 24 h periodicity. Thus it is clear that the rhythm of activity is more like a sine wave than a step function. The time \( t \) x 24 h sine wave factor was often important, as had been expected from examining the data plots. Some chicks had shown greater activity in the active periods during the first two days whilst others had shown greater activity during the latter part of the recording period. All of the above mentioned factors were included in the multiple regression whose residuals were later subject to spectral analysis.

‘Activity previous’ and ‘activity two previous’ were factors which were included in multiple regression analysis but not when residuals were produced since they obscure some short-term rhythms. ‘Activity previous’ was always the most important factor in the multiple regression for the animals sampled at 5 min intervals and was usually the most important for those sampled at 30 min intervals. As would be expected, ‘activity previous’ was less important amongst chicks which showed strong short-wavelength periodicities and more important amongst those with strong long-wavelength periodicities (Table VI). The data for this table are from regressions of activity counts against the single factor ‘activity previous’. The multiple regression analysis results thus support the evidence from spectral analysis for the existence of periodicities of wavelength 24 h and others of much shorter wavelength.

Effects of Rearing Conditions on Activity Rhythms

Spectral analysis showed that periodicities of wavelength 24 h were weak or absent in four of the 16 G chicks but in only one of the 16 O chicks. It seemed possible that the 24 h periodicity was less clearly shown by the G Chicks.

The ratio of the 24 h point to the overall spectrogram mean at longest lag was therefore calculated for each bird (as in Fig. 7). The median ratios were: 30 min samples, 8 for O, 5 for G \((P < 0.01)\), and 5 min samples, 34 for O, 12 for G \((P < 0.05)\). Similarly, in regression analysis the mean reduction in the total sum of squares due to the 24 h sine wave was more amongst O birds than amongst G birds (30 min samples \( P < 0.1 \), 5 min samples \( P < 0.01 \)). There was no such difference between G and O birds in multiple regressions which included the 24 h square wave. The O chicks might be expected to show more obvious 24 h periodicities in their activity levels because, due to their greater activity, the 24 h periodicity would be masked less by noise and short-term rhythms. If the chick showed greater activity during its most active period but no greater activity during its less active period, there would be a higher peak on the spectrogram and a closer correlation with the 24 h sine wave in the regression analysis. The activity level effect cannot explain all of the difference in long-term rhythms because three of the G birds showed no 24 h periodicity but it may account for much of the difference between the other 13 G chicks and the 16 O chicks. There was no evidence for any difference between G and O in the time of day of the most active phase in a 24 h rhythm. Birds in adjacent cages were often inactive at the same time of day.

There were no differences between G and O chicks in the wavelengths of any short-term rhythms of activity. The greater activity of the O chicks resulted in their showing slightly more peaks at any level of significance but the overall distribution of peaks after the removal of the trends and 24 h periodicities was similar for the two rearing conditions (Table VII).

Discussion

Domestic chicks in their first week of life showed clear long-term and short-term periodicities in their activity levels despite being kept in conditions in which there was little variation in temperature and none in any aspect of their visual surroundings. The clear 24 h periodicity, which was shown by most of the chicks, could have been triggered by sounds made by people in the building above the chick room. Aschoff & Meyer-Lohmann (1954) have described periodicities of wavelength 24 h in the activity
Table VI. The Importance of Activity in the Previous Sampling Interval as a Regression Factor in Relation to the Periodicities Demonstrated by Spectral Analysis

<table>
<thead>
<tr>
<th>Chicks</th>
<th>% reduction of total sum of squares due to activity previous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mdn</td>
</tr>
<tr>
<td>All 32</td>
<td>22%</td>
</tr>
<tr>
<td>11 with strongest long-wavelength periodicities</td>
<td>48%</td>
</tr>
<tr>
<td>7 with strongest short-wavelength periodicities</td>
<td>10%</td>
</tr>
</tbody>
</table>

Table VII. Short-term Rhythms of Chicks in Grey Pens (G) and Chicks Which Could See a Moving Object (O) (After Removal of Trends and 24 h Periodicities)

<table>
<thead>
<tr>
<th>No. of peaks at ( P &lt; 0.001 ) level:</th>
<th>30 min sample interval</th>
<th>G</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Median wavelength of all peaks at ( P &lt; 0.001 ) level (h)</td>
<td>2.7</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Median wavelength of all peaks at ( P &lt; 0.05 ) level (up to max. of five per chick)</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

levels of young domestic chicks kept in conditions of constant light and temperature. Gray (1962) found that chicks showed a greater preference for hen over age-mate between noon and midnight but not in the other half of the day.

Most of the chicks in this study showed periodicities with wavelengths of about 2 h and about 30 min, although there was considerable individual variation in the wavelengths. The possible existence of environmental rhythms with these periodicities was investigated but none was found. Some synchronization of phase in 24 h periodicity was found so both long- and short-term rhythms could have been exaggerated slightly by social facilitation effects. The shortest rhythms found in this study are very similar to the cycles with a mean of 25–30 min reported by Guyomarc’h (1975) who watched hens with chicks in a semi-natural field situation and also two chicks isolated in cages. Guyomarc’h’s analysis methods did not readily allow the description of more than one rhythm in an activity record.

Short-term activity cycles with a wavelength of about 30 min have also been reported by Slater (1974) for zebra finches. In a study of feeding behaviour Slater found 24–30 min cycles of feeding activity by using autocorrelation analysis. Subsequent studies on zebra finches showed that, like the chick in the current study, there was considerable variation amongst individuals in activity rhythms. Some showed irregular rhythms whilst others showed clear cycles of activity whose commonest wavelength was 40 min (Slater 1975; Slater & Wood 1977). When zebra finches were subjected to 20-, 30-, 40- or 50-min light cycles, most but not all birds synchronized their activity best with 30 min cycles (Slater & Wood 1977). Guyomarc’h et al. (1973) showed that the activity cycle of young chicks had a mean wavelength of 29 min if the eggs were not subjected to any periodic event but if the eggs were turned every 20 min in the incubator they showed a 21 min activity cycle after hatching. A periodicity of about 2 h has been described by Guyomarc’h & Thibout (1969) for the calling behaviour of adult male Japanese quail.

Chicks show feeding rhythms, sleeping/waking rhythms, and perhaps others, which would affect the amount of walking across the floor sections. The results of this study show that some of these rhythms have active and inactive phases which are sufficiently constant in duration and pattern, during a series of alternations, to approximate to a sine wave. The 24 h periodicity persists throughout most of the time series but the short-term periodicities may last part of the series and then be supplanted by another periodicity of slightly different wavelength. Such variation might be greater in the rapidly
developing chicks studied in this experiment than in older animals. The work of Fentress (1968) on voles and work on chicks in this laboratory (Forrester & Broom, in press) emphasized that the responsiveness of animals is different according to the ongoing behaviour. Culshaw & Broom (in press) have shown that responsiveness is also altered by the time at which a stimulus is presented during a bout of an activity. Such results, and those presented here and by Slater (1974) and Guyomarc’h (1975) which demonstrate the existence of short-term rhythms of activity, emphasize the necessity for considering both the ongoing behaviour of an animal and the possible position of its behavioural state in one or more time series when trying to assess its responsiveness.

A rotating ball like that used in this experiment and similar moving objects elicit approach from young chicks (Smith 1962; Broom 1968) and will also elicit locomotor activity in the form of following if this is possible (see Bateson 1966 for a review). In this experiment chicks which could see a moving object were more active than those reared in grey-walled pens and they spent their time in different parts of the pen. The greater activity level confirms a previous more marked result (Broom 1968). The suggestion in that study that the greater activity of O chicks recorded between 0900 and 1300 hours could be due to differences in activity rhythms not borne out by the present results. The only difference in activity rhythms between G and O chicks which could not be fully explained by the greater activity of O chicks was the weak or absent 24 h periodicity shown by some G chicks. It is possible that the presence of a visible moving object rotating once every 2 s could help to entrain the 24 h periodicity of the O chicks but it has no effect on short-term rhythms.

The greater activity of chicks which can see a moving object might not have been predicted from the observation of Bateson (1964) that chicks in grey boxes crossed a light beam in the centre of the pen slightly more often than did chicks in boxes with black and white walls. However, as suggested in Broom (1968), the chicks with the conspicuous wall pattern may have spent more time by the walls and crossed the centre of the box less. The chicks reared with a moving object visible spent more time in the part of the pen near the moving object than did chicks which could not see a moving object. This preference was evident as it counteracted the preference of the chicks in the grey-walled pens for the side of their pen nearest to the sound of another chick. Figure 2 shows that the chicks in grey-walled pens spent most of the first day on floor section D which was the coldest section on the side nearer to the sound of the adjacent chick and they rested most on this day (Fig. 4). This section also includes the food container but as chicks are using up their yolk sac and seldom eat on day 1 (Schilling & Bleecker 1928; Parker 1929; Broom 1968) it is unlikely that the presence of food determined their position. Chicks in grey pens remained close to the sound of the adjacent chick on day 1 but spent more time in other parts of the pen after that day. No such change with age was shown by chicks which could see a moving object. These chicks could see the moving object from any part of the pen but the sound of the adjacent chick might have been much more attractive if the chick was very near it. Thus the moving object chicks could explore the pen from day 1 but grey pen chicks were less willing to explore on day 1 when the attraction of the sound was greatest.

The greater activity of chicks which could see a moving object was especially apparent on days 1 to 4 (Fig. 3). The activity which probably accounts for this difference and which was not shown by chicks in grey-walled pens was running up and down in front of the moving object. This running was normally shown during the active phase rather than as a sporadic, brief movement and would thus account for the more obvious periodicities shown by the chicks which could see a moving object. It also appeared that the chicks which were very active in front of the moving object were more likely to die before 4 days of age. Guyomarc’h (1975) also reported that chicks show greater activity in more complex conditions. When his hens and chicks were in the field or in the laboratory but with earth and leaves on the floor, the active phase in their 30 min activity cycle lasted for longer than if the chicks were on a bare floor in the laboratory.

The results of these experiments should help in the interpretation of experiments in which the early preferences of young precocial animals and the effects on behaviour of early exposure to moving objects are assessed. The existence of short-term rhythms of activity may explain some of the variance in responsiveness found by those working with chicks and other species. The methods used in this paper and explained fully
in Broom (1979) provide a means for investigating such rhythms.

Acknowledgments

I thank W. J. Jones for designing an electrical circuit, R. Dawkins, R. D. Stern and D. G. Neal for programs and advice on statistical methods.

REFERENCES


(Received 20 November 1978; revised 17 January 1979; MS. number 1836)