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GENERAL BIOLOGY

Is the Periodic "Spontaneous" Activity of Animals Determined by a Quasi-Rhythmic Factor of the External Environment?

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Abstract——We have studied the dynamics of the singing of garden bunting (*Emberiza hortulana*) and the dispersal of a flock of starlings (*Sturnus vulgaris*) for the night rest. The results were compared with the body temperature fluctuations measured in parallel in a group of laboratory mice. The validity of such comparisons was determined by the presence of a stable correlation between the indicators of minutely changes in body temperature in mice and greenfinches (*Chloris chloris*). The increase in the frequency of chanting of garden buntings was observed simultaneously with the increase in body temperature in mice. Moreover, the exact moments of the flights into the birdhouse for the night in starlings coincided with the maximums in the dynamics of minutely changes in body temperature of mice. These facts suggest an external synchronizer of "spontaneous" fluctuations of the activity and associated changes in body temperature, which are probably determined by the tone of the sympathetic nervous system.

Keywords: rhythms of activity, body temperature, synchronizers, mammals, birds

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The periodic changes in activity of different classes of animals are known and have been studied for a long time [1]. In particular, the dynamics of singing intensity in great reed-warbler (*Acrocephalus arundinaceus*) shows periodic increase of song duration in a range of 4–20 min along with the shortening of interval between them, alternating with the period of shorter songs with more extended time intervals between them [2]. Thus, the fluctuations of motivation to singing are probably determined by the level of arousal in birds. Currently it is still unclear whether these fluctuations in animal activity are endogenous or associated with environmental factors.

The presence of these rhythms in taxonomically distant organisms indicates the fundamental characteristics of activity of the central nervous system. The periodic changes in EEG response to repetitive identical stimuli are caused by modifications of spontaneous activity of the nervous system [3, 4]. Moreover, it is commonly believed that insignificant fluctuations of the body temperature related to the changes in sympathetic and parasympathetic activities are endogenous [5, 6].

The results of our studies showed that starlings were mostly eating simultaneously within a 100 km distance from each other, suggesting the synchrony of motivational eating behavior [7]. Furthermore, the total body temperature patterns had an identical set of first harmonics in 10–120 min range appearing synchronously in several species of mammals and birds with different metabolic levels. Therefore, the period of body temperature fluctuations is not determined by the inner features of an organism and supposedly reflects the influence of external biotropic environmental factors [8].

The purpose of this study was to detect the changes in the dynamics of chanting in garden bunting and dispersal of a flock of starlings for the night rest and to compare them with the body temperatures of laboratory mice measured in parallel.

The garden bunting was selected as a appropriate subject for studying the chanting dynamics since its song consisting of short individual warbles. A total of 7 h of singing were analyzed, recorded from three different males. Of them, 3 h were at night and 4 h, in the morning. The observations were conducted from June 9 to 12, 2020, when most males were not actively singing and busy fledging. The observations during this period minimized the probability of arousal of birds provoked by singing of conspecific males.

As the estimation parameter for the rhythmicity of decision-making, the dynamics of dispersal of a flock of the common starlings for the night rest was used. The tests were conducted from May 1 to 13, 2020, during egg-laying and brooding when females overnight in the birdhouse. Overall, 29 birdhouses were hanged and stocked on an area of 30 a. In the evening,

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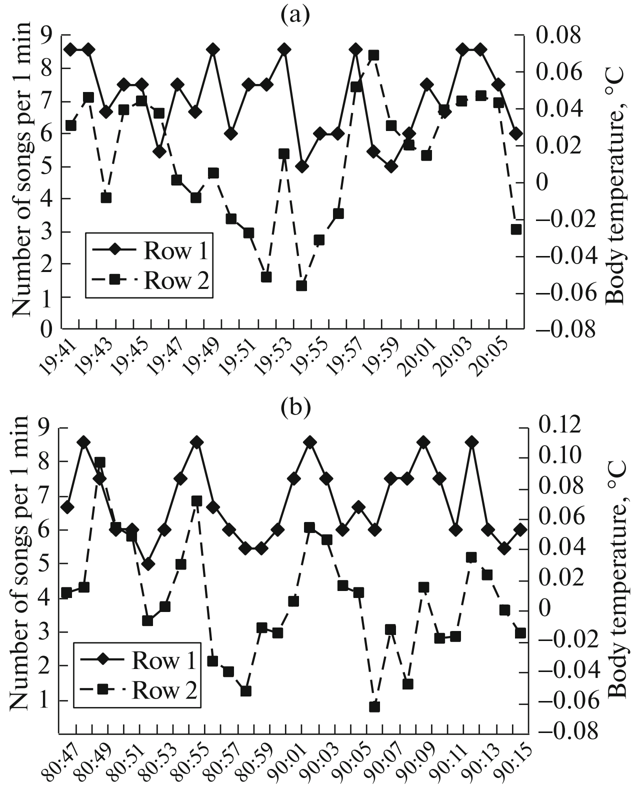

Fig. 1. Examples of the dynamics of singing intensity (number of warbles per min) of garden buntings (row 1) and minutely changes of body temperature in a group of mice (row 2). *A* designates the moment of evening singing on June 9 ($r = 0.41$, $p = 0.036$) and *B* stands for the period of morning singing of June 10 ($r = 0.42$, $p = 0.02$).

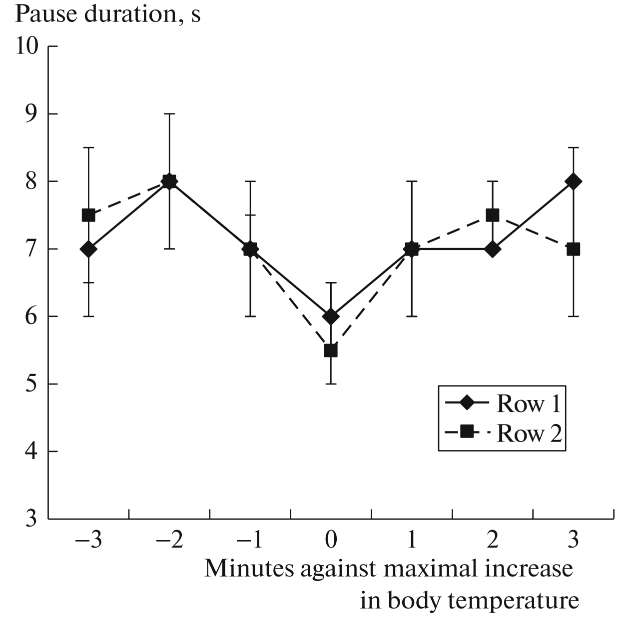

Fig. 2. The distribution of interval duration between warbles in a song of garden buntings against maximal minutely fluctuations of body temperature in mice using epoch folding method (row 1 shows data for the morning, and row 2, for the evening). The data are presented as median and interquartile range.

depending on the weather, starlings nestled in flocks on the nearest and highest trees 30–60 min before bedding down, from where a few animals at a time flew to the birdhouses over 20–40 min. The advantage of this monitoring was in deciding flying with the background of calm evening resting of birds. The flying time was detected with an accuracy of 1 min. The longest and most informative series were received in fair windless weather, when the duration of evening rest and the interval between flying into the birdhouse of the first and last animals were maximal. The examinations mentioned above were performed in Spassky district of Ryazan oblast.

The body temperature dynamics in laboratory mice and greenfinches (*Chloris chloris*) was recorded simultaneously for the period from March to April 2020. The dynamics of intraperitoneal body temperature was recorded once a minute using an implanted intraperitoneal DTN3-28 transducer (Emby Research, Novosibirsk, Russia). Intraperitoneal transducer insertion was conducted using zoletil anaesthesia (Vibrac Sante Animale, France) administered intramuscularly at a dose of 7–10 mg/kg. The conditions of artificial permanent, but not bright lighting were created for laboratory mice ($n = 7$) with an intensity of 600 lx, while birds ($n = 6$) were kept in the natural light.

Although the analysis of individual rhythms is essential, for the current experimental purposes, we used median of minutely body temperature fluctuations in a group of animals, reflecting the integrative reaction of different animals. Spearman correlation coefficient was applied to the medians of values in groups of mice and greenfinches depending on the date and varied from 0.08 ($p = 0.01$) to 0.24 ($p = 0.004$). The analysis of coincidence between median extremes of minutely body temperature measurements in mice and greenfinches showed their coincidence within a rhythm range of 4–16 min with the accuracy of ±1 min in 78% of cases. Thus, the rhythmic fluctuations of body temperatures in mice and birds were synchronous and probably associated with a certain quasi-rhythmic environmental factor.

Figure 1 shows an example of the dynamics of changes in singing intensity of garden bunting and the body temperature of mice: either 4-min changes or 6- to 12-min ones predominated in the dependence from the experimental day. The Spearman correlation coefficient was statistically significant in the investigated parameters. Furthermore, the coincidence of singing intensity and body temperature fluctuations was performed using the epoch folding method. The distribution was then constructed for the index of interval duration between the individual warbles of buntings

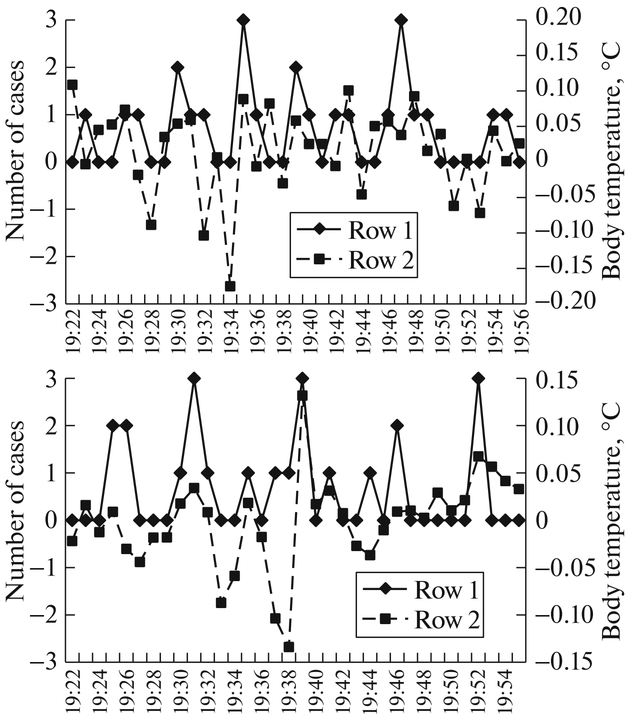

Fig. 3. The dynamics of settling for the night rest in starlings (row 1) and minutely changes in body temperatures of mice (row 2). *A* represents May 3, an example of 4-min fluctuations ($r = 0.17$, $p = 0.31$); *B* shows May 5, an example of 6- to 8-min changes ($r = 0.22$, $p = 0.23$).

and different extremes of body temperature fluctuations in a group of mice (Fig. 2). It was discovered that the interval durations between individual warbles was 5–6 s in the period of extreme point in body temperatures of mice, while it fluctuated in the average range of 7–8 s. The indices differed statistically during the period of maximal increase in the body temperature (the zero minute) and 2 min before and after the event ($p = 0.0003$ in Mann–Whitney test, $z = -3.5$). Therefore, there is a direct relationship between the intensity of bird singing that reflects its physiological condition and the body temperature fluctuations.

Figure 3 contains examples of a parallel recording of the number of starlings flying into the birdhouse and minutely changes in temperatures of mice: 4-min rhythmicity prevailed on May 3, whereas the 6- to 8-min rhythmicity was predominant on May 5. The correlation coefficients were statistically insignificant. Nevertheless, a positive correlation was seen between the distribution of all recorded bird flights into the birdhouse and the maximal medians of minutely body temperature fluctuations in a group of mice: 92 flights of starlings were detected in the period of maximum and only 27–32 cases were detected 2 min before and after the maximum ($p < 0.001$ in z test for estimation of two sampling rates, $z = 5.99$, Fig. 4). Thus, a correlation was established between common maximal values

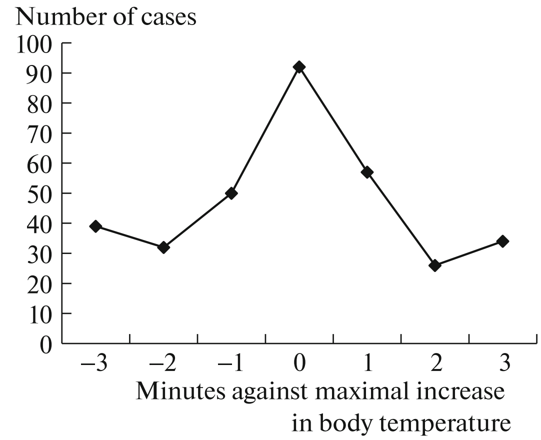

Fig. 4. The distribution of dispersal for the night rest number in starlings against maximums in the dynamics of minutely fluctuations of body temperature in mice using epoch folding method.

of minutely changes in body temperature in birds and mammals and decision-making regarding the dispersal for the night rest of starlings.

The body temperature fluctuations within 4–16 min was correlated with the changes in geomagnetic field there is a number of other physical factors that are characterized by the same frequencies in their spectrums [8, 9]. The nature of the external synchronizer is yet unknown. Referring to the results introduced in this study, it can be proposed that such forms of “spontaneous” activity in birds as singing intensity and decision-making on flying for the night rest into the birdhouse are not accidental in time, but rather associated with periodic fluctuations in body temperature within 4–16 min, which are, in turn, determined by sympathetic activation and are probably influenced by external synchronizers.

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COMPLIANCE WITH THE ETHICAL STANDARDS

The experimental procedure was approved by the ethical committee of the Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, protocol no. 14, January 15, 2018.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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