A RADIO-BIOTELEMETRY SYSTEM FOR MONITORING BODY TEMPERATURE AND ACTIVITY LEVELS IN THE ZEBRA FINCH

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It is important that physiological data be obtained from an animal without disrupting its usual activity patterns. King and Farner (1961) suggest that avian body temperature should ideally be measured in darkness, at the time of postabsorption, and taken in the cloaca, proventriculus, or pectoral muscles. Measurements of this sort are difficult or perhaps impossible to obtain accurately without restricting and/or disturbing the test animal.

Boyd and Sladen (1971) discuss the advantages of radio-biotelemetry over other methods for the measurement of body temperature in long-term studies. Long-term investigation of body temperature by conventional methods introduces the possibility of error from handling. Radio-biotelemetry has the advantages of continuous recording, ability to monitor from a distance, and reduced disturbance.

Several papers in the literature pertain to radio-biotelemetry and its use with birds. Tracking studies using pigeons (Michener and Walcott, 1966) and owls (Nicholls and Warner, 1968) provide ecological information on movements and habitat preferences. Single channel physiotelemetry has given good results in the areas of ECG (Owen et al., 1969) and respiration (Lord et al., 1962) without notably interrupting normal behavioral sequences. Multichannel physiotelemetry has proved successful (Roy and Hart, 1963, 1966), although the size of the telemetry package restricts its use to birds as large as or larger than a pigeon. To my knowledge no telemetry work has been done on birds as small as the Zebra Finch (*Poephila guttata*). The technique of using telemetry to monitor locational or physiological information in birds is still in the developmental stages although many problems have been overcome.

Materials and Methods

The Zebra Finches used in this experiment were all approximately 8 months old, in good condition, and successful in raising broods of young. All of the Zebra Finches had been paired and placed in separate cages before completing adult molt. Both controls and the test birds remained in their breeding cages during the experiment.

As the surface temperature in feathered areas of small birds varies only slightly from core temperature in the absence of thermal stress (Bartholomew and Dawson, 1954a, 1954b; Irving and Krog, 1955; Steen and Enger, 1957; King and Farner, 1961) the transmitter was placed on the dorsal feather tract, where it is easily accessible and causes a minimum loss of balance during flight. Birds to be studied

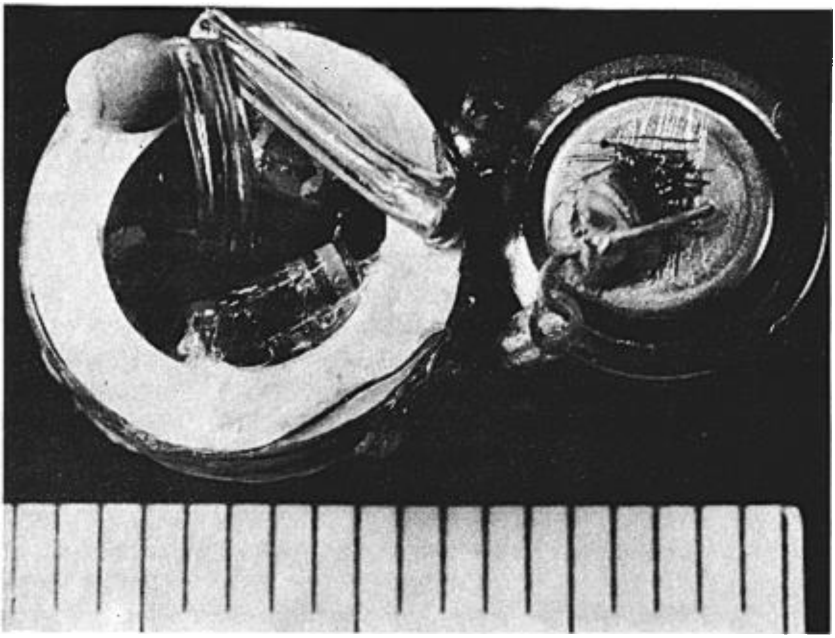

Figure 1. A modification of the transmitter designed by Spencer (1968) next to a metric scale. This device employs a Hartley blocking oscillator with a current drain of 0.2 ma from a 1.25 volt (RM 312) power supply. This combination of characteristics provides a temperature-sensitive transmitter weighing 1.7 g with a range of 3 m and a life of up to 12 days.

were first placed under light Metaphane^{R} anesthetic and the feathers of the dorsal feather tract immediately posterior to the crop were plucked down to approximately 0.5 cm past the scapular area. A 24-hour recovery period was allowed for the skin of the dorsal feather tract to recover from the plucking effects. The birds were then again placed under light Metaphane^{R} anesthetic and the transmitter attached by gluing it with Eastman 910^{R} surgical contact adhesive.

Feather removal stimulates each dermal papilla to regenerate an epidermal collar and to begin growing a new feather. The new feather growth dislodged the transmitter in 3 to 7 days. Test runs did not exceed 60 hours, to avoid error due to transmitter displacement.

Figure 1 shows the transmitter before potting in beeswax. The circuit is assembled in the transmitting coil and fixed by G.C. Q-Dope. The transmitter is then activated for a week to age the components and avoid frequency and calibration alterations during the test run.

Spencer's (1968) transmitter was designed to provide a pulsation frequency of 2 to 20 pulses per second over a temperature range of 10°C to 50°C. In our studies the low pulse rate proved inadequate to detect changes of the order of 0.1°C in the bird's surface temperature. Therefore the number of pulses corresponding to temperature were increased by changing the capacitor of the RC pulsing circuit (C_1, Figure 2) to 0.001 MFD initiating pulse ranges of 500 to 5,000 pulses per second

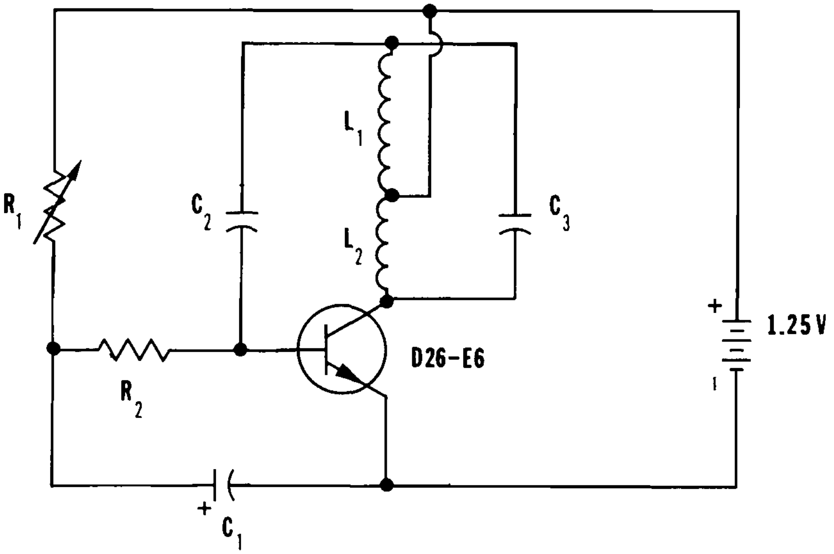

Figure 2. The circuit diagram for the temperature transmitter designed by Spencer (1968). The components used in this application are R_1 = 300K YSI thermistor bead at 25°; R_2 = 1 K 1/8 watt Allen-Bradley; C_1 = 0.001 MFD electrolytic Capacitors Inc. Biddleford, Maine; C_2 = 0.001 MFD chip capacitors Guyton Electronics; C_3 = 0.001 MFD chip capacitors Guyton Electronics; Male, L_1 = 25 turns, L_2 = 8 turns (90 Khz); Female, L_1 = 30 turns, L_2 = 13 turns (120 Khz); D26-E6 = General Electric micro-tab transistor; Battery = RM 312.

in the range of 30° to 40°C. This made the pulse rate approximately 500 pulses per 1.0°C. Body temperature and activity patterns were monitored from the male and female pair simultaneously on two separate frequencies (90 Khz and 120 Khz) obtained by changing the number of windings on the oscillating coil (Figure 2). The current drain was 0.2 ma giving a transmitting life of 12 days using a RM 312 battery. Accuracy is maintained by using Mallory R series mercury cells to reduce calibration drift due to ageing.

The transmitters were calibrated in an oil bath in which the temperature was increased by 0.5°C increments from 30° to 40°C. A calibration curve (temperature versus frequency) was plotted by regression analysis of the 2°C segments.

The three primary methods used for data recovery were direct frequency conversion (Figure 3B), qualitative temperature change (Figure 3A), and qualitative temperature change combined with activity level measurements. The second of these three methods was discontinued when it became possible to recover the same data in less time using a Grass oscillograph. It is included here for researchers who may not have access to an oscillograph.

Direct frequency conversion as illustrated (Figure 3B) was accomplished by sampling from the frequency counter at intervals and converting to degrees centigrade. The conversion was accomplished by reading the equivalent temperatures from a calibration graph completed for each transmitter by regressional analysis.

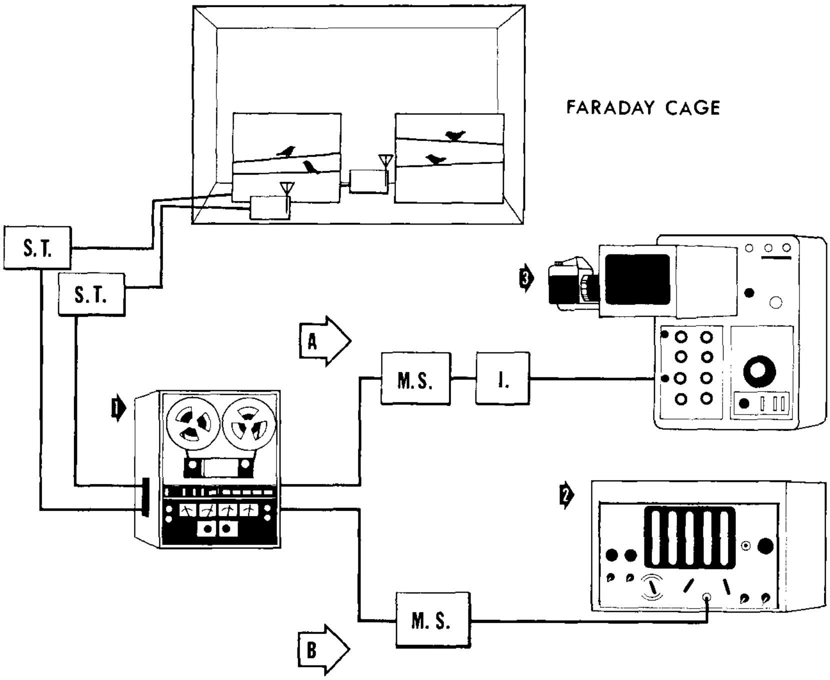

Figure 3. Data collection and data reduction systems. The signal is received by commercial Panasonic^{R} AM-FM transistor radios placed inside the Faraday cage. The received signal is processed by Schmitt triggers (R.C.A. CA–3001) acting as low band pass fitters and recorded on magnetic tape (Sony TC–9540 1.). The recorded data are analyzed through channels A and B. In channel A the signal pulses are fixed as to duration and amplitude by a monostable multivibrator (F.G.S. 914) and integrated onto an oscilloscope (3) for photographing. In channel B the signal pulses are passed through a monostable multivibrator for pulse shaping to a frequency counter (Hewlitt Packard 522B) where the frequency is sampled for quantitative surface temperature measurements.

Patterns of temperature change were obtained by photographing the integrated signal from an oscilloscope (Figure 3A). Although this method gives usable results, much time must be spent in photographing, developing, and sampling. If an acceptable oscillograph is available, it will give superior results and save time.

Activity levels and qualitative temperature change were recorded on a Grass oscillograph. It was possible to recover activity data because of the inability of the receivers to follow rapid changes in the position of the transmitting coil. Therefore when the birds flew or moved quickly on the perch a temporary signal null was recorded. The recorded signal was integrated and played into a Grass oscillograph and each of the signal nulls corresponding to movements were recorded as high amplitude deflections (Figure 4). The deflections were counted and graphed to give the activity levels of the test birds (Figures 5 and 6).

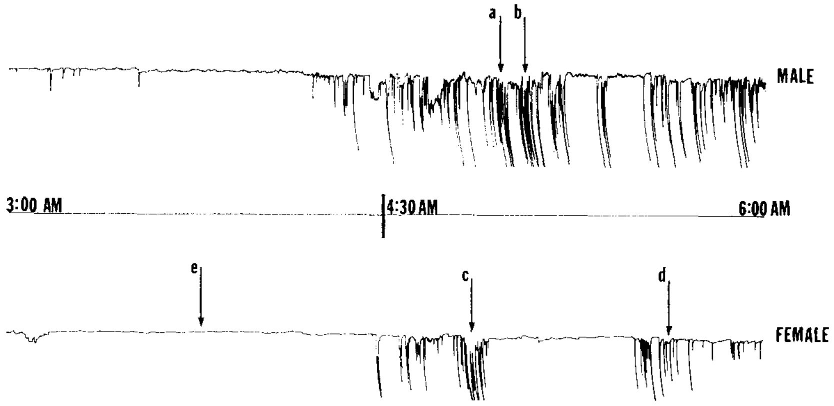

Figure 4. Oscillographic recording of male and female Zebra Finches illustrating the method for determining activity levels. Incipient early morning behavior has been selected to show the three types of activity discernible by this method. (a) and (b) in the male trace, and (c) in the female trace, show high intensity movements typical of flying. (d) is a trace commonly found with movements on the perch such as preening or bill-wiping. (e) shows the complete absence of activity that occurs in the nest box during the nighttime rest period.

RESULTS

Surface body temperature and activity data were recorded from six mated pairs of Zebra Finches for a total of 209 hours (Table 1). A statistical comparison of activity and thermoregulatory data between the

TABLE 1

ACTIVITY AND TEMPERATURE VARIATION FOR MALES AND FEMALES DURING 209 HOURS OF RECORDING

Test run	Sex	Activity periods Maximum	Activity periods Minimum	Temperature variation	Photoperiod	Room temperature
1. 24 hours	Male	04:00–07:00	07:00–15:00	1.9°C	11 hours of light	21°–22°C
	Female	03:00–07:00	07:00–15:00	1.7°C		
2. 24 hours	Male	15:00–18:00	24:00–04:00	2.0°C	11 hours of light	20°–22°C
	Female	14:00–19:00	22:00–04:00	1.9°C		
3. 45 hours	Male	09:00–12:00	21:00–03:00	2.4°C	12 hours of light	20°–22°C
	Female	12:00–15:00	21:00–03:00	2.3°C		
4. 36 hours	Male	15:00–18:00	21:00–03:00	1.5°C	12 hours of light	21°–22°C
	Female	15:00–18:00	21:00–03:00	1.7°C		
5. 24 hours	Male	15:00–18:00	18:00–03:00	2.1°C	12 hours of light	22°C
	Female	15:00–18:00	18:00–03:00	1.7°C		
6. 56 hours	Male	14:00–18:00	24:00–04:00	2.2°C	12 hours of light	20°–22°C
	Female	14:00–18:00	24:00–04:00	2.0°C		

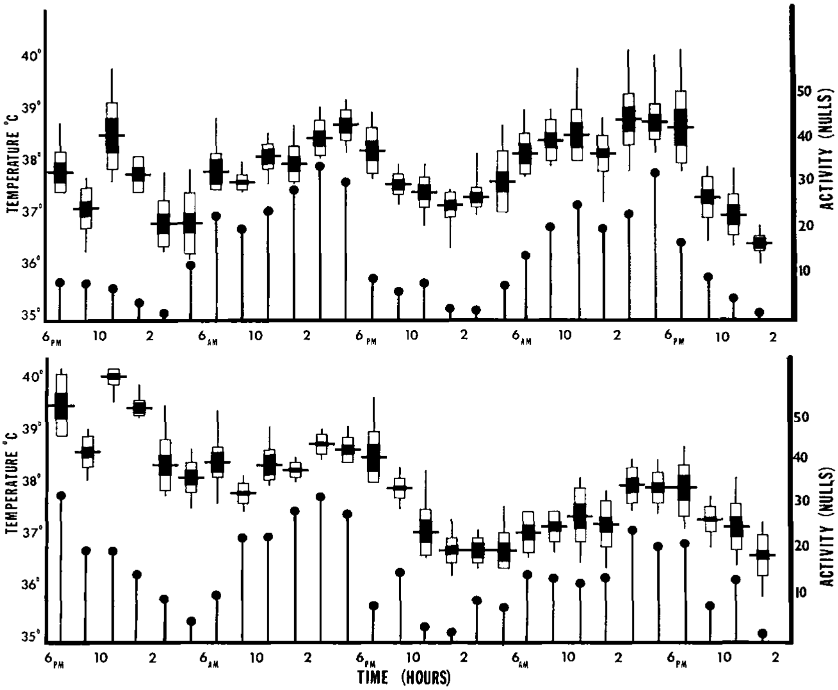

Figure 5. Graph showing the relationship between body temperature and activity levels for the male (top) and female (bottom) in test run 6. Body temperature is represented as follows: A horizontal bar for the mean, a vertical bar as the range, a solid black rectangle for the standard error, and an open rectangle for the standard deviation. The activity levels are represented as solid circles, the sum of the nulls recorded on the oscillograph for each 2-hour period.

males and females showed no significant difference between the two groups. The average daily temperature variation for the test group (males and females) was 1.95°C. The mean skin temperature for all of the males and females tested was 37.3° and 37.1°C respectively. Maximum activity occurred during the daylight hours between sunrise and sunset with characteristic activity peaks between 15:00 and 18:00 (Figure 5).

Figure 6 represents room temperature during the 56-hour test period. The variation is 2°C over a range of 20° to 22°C. Skin temperature in birds differs from core temperature during hypothermia (Steen and Enger, 1957) and hyperthermia (Bartholomew and Dawson, 1954a), but the effects of relatively slight changes in ambient temperature during the absence of thermal stress need further study.

Figure 5 represents 56 hours of continuous recordings of male and

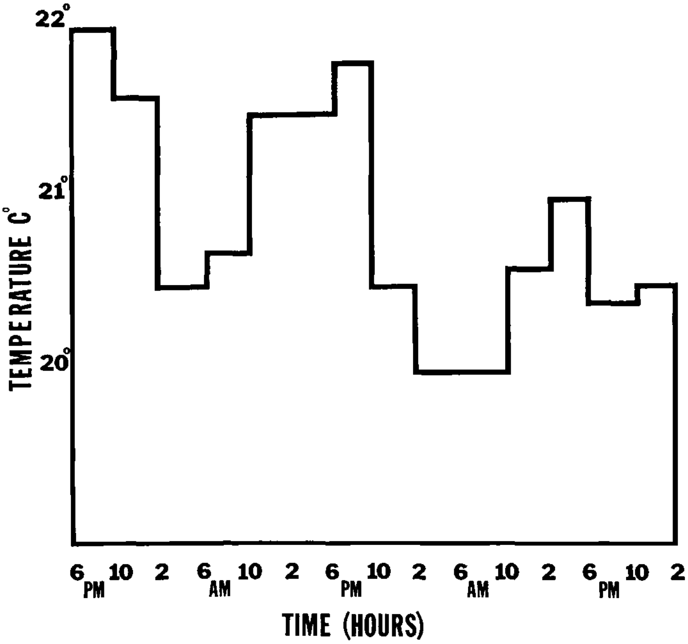

Figure 6. Room temperatures during the 56-hour test period.

female body temperature and activity levels. The first 12 hours of both recordings show activity and skin temperature levels that are not characteristic of the majority of the nocturnal patterns recorded for the animals tested. These atypical recordings are probably the result of a disturbance extreme enough to make the birds fly in the dark. After the first 12 hours both graphs show the activity and skin temperature patterns more typical of all the animals tested. The daily cycle begins with low nocturnal activity when the birds are asleep or unable to fly because of darkness. This period is followed by a marked increase in activity beginning at sunrise and reaching a peak between 15:00 and 18:00.

The periods between 15:00 and 18:00 that show the highest levels of skin temperature and activity correspond to the feeding period characteristic of Zebra Finches, both in the wild (Immelmann, 1965) and in the laboratory.

Similar body temperature patterns occur in the Ruby-throated Hummingbird (*Archilochus colubris*) (Pearson, 1953) and Gambel's Quail (*Lophortyx gambelii*) (Woodard and Mather, 1964). The metabolic rate of both birds reaches its maximum just before 18:00. No explanation is offered for this metabolic climax in either of the above, but in the case of Zebra Finches, which exhibit active search and feeding during this period, I suggest that the combined effect of increased activity and the chemical thermogenesis of digestion are probably responsible for the body temperature peaks exhibited in Figure 5.

DISCUSSION

The 24-hour thermoregulatory cycles in Zebra Finches are comparable to the data presented for various other birds by Bartholomew and Cade (1957), Bartholomew and Dawson (1958), and Dawson (1958) and many others. Although little has been written concerning the thermoregulatory cycles in Old World finches (*Ploceidae*), Dawson (1954, 1958) has described these cycles in species of Fringillidae.

Daily cycles of thermoregulation and activity appear to be mechanisms for energy conservation. The extremely small body size of Zebra Finches and the consequent large surface-to-volume ratio necessitate energy conservation. The methods of solving energy problems in nature are quite varied although 24-hour rhythmicity as it applies to activity and body temperature is by far the most common.

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SUMMARY

A telemetry system has been designed to monitor surface body temperature and activity levels in the Zebra Finch (*Poephila guttata*). The use of radio-biotelemetry allows for continuous recordings of body temperature, perching, feeding, and preening activity in mated pairs of Zebra Finches, without interrupting usual daily behavior patterns.

Under light Metaphane^R anesthetic, a temperature transmitter was glued to the dorsal intrascapular surface of the birds. The transmitters weighed approximately 1.7 g and were sensitive to 0.1°C temperature change over a 30°C to 40°C range. The telemetered data were radio-detected, demodulated, and stored on magnetic tapes for later analysis.

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