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BRIEF COMMUNICATION

Web-Building Time in a Spider: Preliminary Applications of Ultrasonic Detection

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RAMOUSSE, R. AND F. DAVIS. *Web-building time in a spider: preliminary application of ultrasonic detection.* PHYSIOL. BEHAV. **17**(6) 997–1000, 1976. – Data collection on time and length of building in orb-weaving spiders has suffered from absence of light during construction and inconvenient hours. A simple apparatus is described which permits recording of the spiders' movements as they disturb an ultrasonic field. By varying onset and length of dark periods for two animals at even temperature and by registering the building periods for 127 webs, a definite influence of the light-dark cycle can be identified: there is a strong preference for building webs in the dark; this is superimposed on the circadian rhythm of orb-web construction. One of the spiders always built earlier than the other.

Circadian rhythm   Web-building   Onset and length of darkness   Ultrasonic detection of movement

SEVERAL investigators [4, 6, 9] have studied factors which influence frequency of orb-web building. The time of building, however, has only been extensively recorded with actographic methods in *Nemesia caementaria* [1] and in *Agelena consociata* [3]; these spiders do not build orb webs. In *Araneus diadematus or Zygiella-x-notata* there are only some observations indicating a daily building time around 5:30 a.m. [7], or a seasonal change from 2:00 a.m. in summer to 5:00 a.m. in the fall [9]. Light-dark and temperature cycles have been suspected to play a role in setting the time, but the inconvenient hour of building and the low visibility for direct observation in the early morning hours have prevented investigators from obtaining sufficient data.

Knowledge on web-building time is essential for the understanding of the builder's survival. An animal like *Araneus diadematus* alternates between nearly 23 hours of immobility, waiting for prey – only interrupted by short excursions toward an entangled insect, – and about one hour of dismantling the old and constructing the new web. We can assume that timing is adjusted to maximum chances of prey catching, and that it varies from species to species and according to prey activity periods. Does the daily cycle of building and waiting depend only on the inner rhythm of an animal, or can environmental cues cause an adaptation to specific circumstances? This preliminary note describes an ultrasonic methodology and first results of the consequences of light–dark shifts for one orb-web builder, the cross-spider *Araneus diadematus* Cl.

METHOD

The Recorder

Web-building activity was recorded with an ultrasonic system of motion detection. This system was chosen because:

(1) The threshold response in spiders is observed at relatively low frequencies, so that the 75.5 kilohertz (kHz) tone of our instruments is well beyond the spider's high frequency threshold (2,5). It does not seem to interfere with the spider's normal activity.

(2) The wave-length of 75.5 kHz, under normal atmospheric conditions, is 4.39 mm; objects of this size are easily detectable. The length of the two spiders used was more than 5 mm.

(3) Movements are permanently recorded on pressure

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sensitive paper running at 5 cm/hr. The recorder samples its output once every 3 sec giving approximately 1200 points per hr, which is enough to detect any rapid change.

The device (Fig. 1 & 2) consists of five units: (1) the sending unit; (2) The cage; (3) The receiving unit; (4) The recorder; (5) The power supply of ± 15 and 5 volts for all circuits.

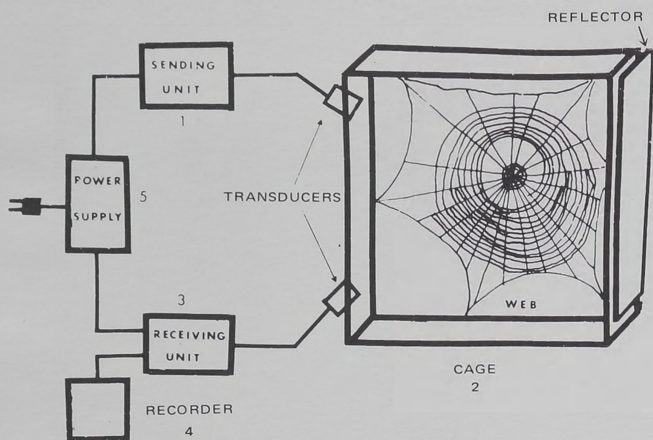

FIG. 1. The five units of the recording device with spider cage and web.

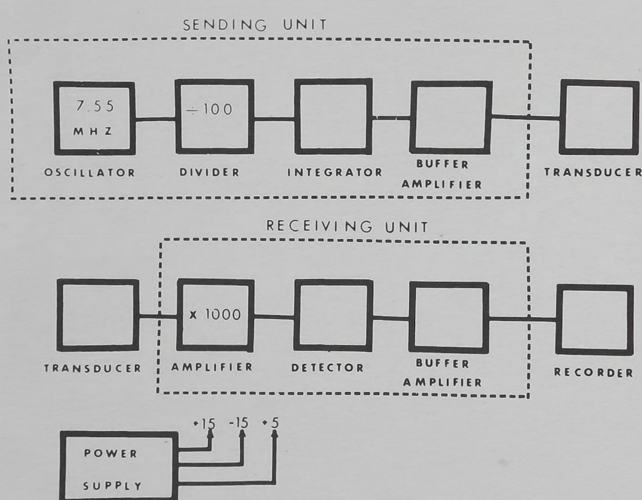

FIG. 2. Details of the sending unit, the receiving unit and of the power supply.

The sending unit employs a quartz crystal oscillator for frequency stability, since shifts in frequency would produce spurious signals and drift. The frequency of the quartz crystal is 7.55 Megahertz (MHz), which is divided to produce a frequency of 75.5 kHz. The square wave output of the divider is converted approximately to a sine wave and fed via co-axial cable to the sending transducer (which functions as a speaker). This establishes an ultrasonic field inside the cage.

The cage is a 50 × 50 × 10 cm aluminum frame with glass sides and screen wire edges. The two transducers are mounted on one side aimed at the reflector on the other side. Movements of the spider within the ultrasonic field create disturbances which are sensed by the receiving transducer (which functions as a microphone) and fed via co-axial cable to the receiving unit. Here they are amplified to drive the analog recorder.

The National Aeronautics and Space Administration (NASA) adapted this type of system for the spider experiments for the Biosatellite program (Witt, personal communication) but did not use it.

Recording Conditions

Araneus diadematus spiders were placed in the above described frames. The frames were in a closed black box where light and temperature could be controlled and recorded (Fig. 3). The box was lit with a 25 W fluorescent bulb and a 100 W yellow incandescent bulb. Temperature increased slightly during the light period (2° C).

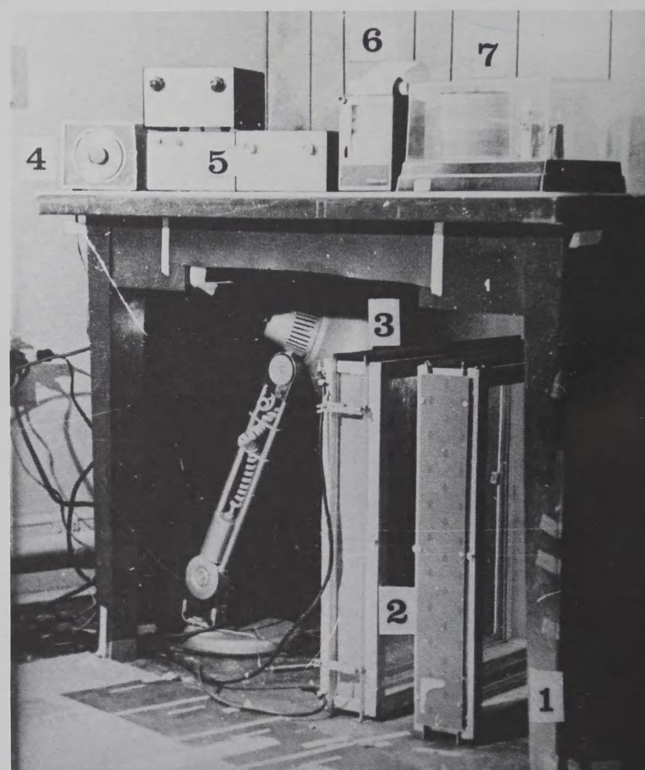

FIG. 3. Experimental apparatus: (1) Black box, front removed; (2) Spiders' cages: one presenting the sound reflector end, the second presenting the two transducers; (3) The light; (4) The timer; (5) The sending and receiving units; (6) The movement recorder; (7) The temperature recorder.

Two females, A and B, from two different cocoons, reared in the laboratory (darkness from 0:00 a.m. to 9:00 a.m., 16° C; light: 22° C) were studied. Both spiders had hatched on the same day.

The spiders were fed a housefly and watered twice a week. As it is known that undisturbed spiders usually spin their web during the dark period, recording started 3 hr before the light was turned off and stopped three hours after the light was turned on. The previous web was collapsed before the recorder was turned on.

The two spiders were recorded under 8 successive conditions of varying light (Fig. 4). In the conditions II, VI,

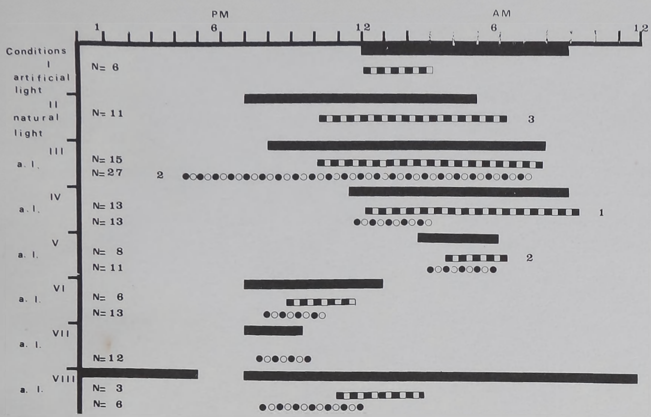

FIG. 4. Time of web-building under different conditions (from onset of building of the earliest web to the end of the latest web). Black bars indicate dark periods. Black and white bars: Spider A, black and white circles: Spider B. The number in front indicates the number of webs begun before the onset of darkness. The numbers at the right end indicate the number of webs finished after darkness. Condition I: condition of rearing with artificial light. Condition II: natural light. Condition III to VIII: artificial light. Only during Condition I was there a distinct temperature difference between light (= warm) and dark (= cool) maintained in the laboratory.

VII and VIII onset of darkness was constant (7:00 p.m.) and the length of darkness was between 2 and 22 hr. In another set of experiments onset of darkness was delayed and length of darkness was between 3.5 and 12 hr.

Analysis of Records

Each record shows the total activity of the spider during the recording period. In an attempt to differentiate web-building activity from other locomotion on a record, we watched the recording for several nights. The recorder and the spider's box were in two different rooms in order not to disturb the recording by non-spider movements. The experimenter looked at the spider in the frame each time a signal appeared on the recorder. During short bursts of activity (less than 5 min) we always saw the spider exploring. In the case of a long burst we saw web-building and exploratory activity. The signals during web-building were always larger in amplitude than during exploration, and web-building occurred at the end of the exploratory phase (Fig. 5). Exploration may replace the period which normally contains destruction of the old web, and which usually precedes building of the new structure.

FIG. 5. Sample records, read downward: (A) Record of web-building only; (B) Record of web-building and exploration. Web-building is the last activity recorded, and the magnitude of the signals of web-building is larger than the signals of exploration; (C) Record with no activity at all.

RESULTS AND DISCUSSION

Duration of Web-Building

The mean lengths of web activity were: Spider A – 80.29 ± 22.01 min, N = 78 webs; Spider B – 73.24 ± 18.67 min, N = 49 webs. No significant differences exist between the two means.

The duration of web-building activity in a night is positively correlated with size of spiral area built in that night (Kendall rank correlation, A and B, $p = 0.001$), indicating that it takes more time to build a larger web.

Building Time

The two spiders started to build their webs always in darkness, with two exceptions which occurred near the molting time of Spider B (Condition III). Sometimes building started close to the end of darkness and was finished during the light period. Most of the time the spiders built a web during the first new dark period following the shift from one condition to the other.

When onset of darkness varied the delay between onset of darkness and onset of web-building decreased with decreasing length of darkness (Friedman two-way analysis of variance, Spiders A and B, $p = 0.01$). Web-building took place later after onset of darkness when darkness was longer.

These results suggest that *Araneus diadematus* builds webs preferably in the dark, where onset of darkness may be a positive (releasing) factor of web-building and onset of light a negative (inhibitory) one. When the dark period lasted very long (Condition VIII), web-building appeared to follow the inner clock more closely. There was also a distinct difference between Spiders A and B, the latter always building somewhat earlier.

According to these observations the dark-light cycle definitely influences web-building even if there is no change in temperature; but only observations of many spiders over long periods of time can establish a more exact relationship between the circadian rhythm of web-building and role of darkness. It also remains to be seen in the future whether different spiders have individual timing, as they have individual web patterns [8]. The new method described here can establish such correlations. Web construction at night can be understood as an efficient device which protects the builder from visually oriented predators, it also provides the spider with the full light period for catching airborne prey. Spiders which specialize on prey which is active at night may show other construction times.

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