Radio Tracking of Homing Bats

Abstract. *Neotropical bats,* Phyllostomas hastatus, *were released 10 kilometers from their home roost, and their homeward flights were tracked by radio. Flights of bats with unimpeded vision were strongly oriented in the homeward direction, while the flights of blindfolded bats did not show this marked orientation.*

The neotropical bat *Phyllostomus hastatus* (Pallas), studied in Trinidad, West Indies, has shown a high level of percent of bats released at a distance of 5 to 10 km from their home roost homing performance. Within 1 night 94 returned to that roost, 57 percent returned from 11 to 34 km, and 26 percent from 40 to 53 km. Many of these bats homed very rapidly; several returned from as far as 32 km at a minimum flight speed of 11 km per hour (*1*). Either highly oriented flights at about this speed or only slightly oriented wandering at higher flight speeds could explain these observations, but data on homing performance do not allow one to distinguish between the two possibilities.

Phyllostomus hastatus weigh from 70 to 100 g and are among the largest bats in the Western Hemisphere. Thus they are able to carry a small radio transmitter in flight. With a directional antenna, we were able to track bats carrying radio transmitters. Those that could see flew rapidly toward home, while others whose eyes were covered by small blindfolds wandered slowly in a random fashion.

The 150-megacycle crystal-controlled transmitters weigh about 7 g, measure 1 by 1 by 3 cm, and have a 25 cm piano-wire antenna which extends behind the bat. The transmitters were attached by two short cords to a piece of nylon net anchored with parlodion to the fur of the bat's lower back. When a bat had returned to its home cave the transmitters were recovered by untying the cords; the bats removed the nylon net along with some fur a few days later. With this method of attachment bats have carried radios for as long as 9 days without any visible ill effects.

The receiving equipment, which was mounted on the roof of an automobile, consisted of an eight-element 150-Mc/sec Yagi antenna on a 6-m mast which was rotated by hand. A compass, attached to the mast, allowed bearings to be read to an accuracy of $\pm 10°$. A 12-channel, crystal-controlled 150-Mc/sec receiver was especially built for tropical field use (*2*). With this equipment it was possible to track as many as three bats simultaneously, or to follow a single bat with the automobile in motion and the antenna on a 2-m mast. The range of the system was about 5 km over relatively flat wooded terrain with the transmitter 6 m above the ground, which we estimate to be the minimum flying altitude of the bats. Daylight observations indicate that their maximum flying altitude is probably not greater than 50 m.

The approximate distance of the transmitter from the receiving antenna was estimated by the average strength of the received signal as compared to the strength of the received signal at known distances. With this criterion we were able to discriminate two distance categories: less than 1.5 km, and 1.5 to 5 km. Often a rapid change of bearing allowed us to place the bat at the nearer end of one of these categories. Our estimation of distance was confirmed in a few experiments in which the receiving antenna was mobile and in which we used triangulation. Figure 1 shows the approximate flight paths of bats as determined by this procedure.

We here include all the data from two release points 10 km from the home cave, one southeast, the other southwest. Both release points were approximately in the center of large clearings about 1.5 km in diameter. The bats were released shortly after sunset; this time corresponds to their normal period of activity in the evening. In all but five of these experiments the receiving apparatus was within 1.5 km of the release point. Bats were handled, transported, and blindfolded as described.

The data from the experiments with bats carrying only a radio and identifying markings are presented in Fig. 1, c and d. In most experiments bats without radios were released the same evening. Of these 20 control bats 14 returned within 1 night, three after 2 nights, one after 5 nights, and two were not recovered. Seventeen bats with radios were released; 13 returned within 1 night, the remainder within 2 nights. These bats flew rapidly and, in an average of 35 minutes, were out of range of the receiver (approximately 5 km). These bats headed in the homeward direction within a few minutes after they were released 10 km from the home roost. They were not simply taking a constant bearing as do certain birds (*3*).

A second group of nine animals was released with their vision completely obscured by the aluminum blindfolds (*1*). Two of the nine returned during the first night, but by the next day the blindfolds were loosened or removed enough to allow some vision. Three returned in 2 nights with effective masks, one returned without its blindfold after 4 nights, two returned with their blindfolds on after 5 and 9 nights respectively, and one was not recovered.

Bats with blindfolds (see *1*) have homed more rapidly than those with both blindfolds and radios, possibly because the combined effects of the two types of encumbrance affected homing speed more seriously than either alone. In Fig. 1, a and b, the flight paths of those bats that returned with effective blindfolds are indicated by solid lines, those of bats that returned with ineffective blindfolds by dotted lines. The blindfolded bats did not fly as rapidly or directly toward the home roost as did those that were able to see. Bats in this group were followed for an average of 154 minutes, and five of the nine experiments were terminated with the bat still within range.

A control group, equipped with "goggles" (*1*), was also released to determine whether the less-well-oriented behavior of the blindfolded group was due to the irritation of the blindfold or to the loss of vision. The control group wore masks similar to the blindfolds except that holes were cut in the aluminum and covered with clear plastic to allow the animal to see. Of the 11 bats released, five returned in 1 day, three with effective goggles; three returned in 2 days, one with effective goggles, one returned in 4 days with its goggles effective; and two were not recovered. Certain of these bats exhibited the rapid, oriented flights similar to those of the group without blindfolds (Fig. 1, e and f). Thus, loss of vision prevented the blindfolded group from showing oriented behavior. Other bats with goggles showed the slow wandering flights characteristic of blindfolded animals. In some of these cases the goggles may have been acting as blindfolds. Two of the bats in this group had so deformed their masks before release that only one of the lenses was transparent. A continuation of this process after release could have transformed the goggles into effective blindfolds.

In six of the experiments described, three bats carrying radios were released simultaneously, one with blindfold, one with goggles, and one without a mask. The behavior of bats released singly or in groups of three was indistinguishable; there was no evidence that one bat followed another.

The difference between the behavior of the blindfolded group and that of the bats which could see indicates the importance of vision for rapid orientation of these animals at the release point. We do not yet know which aspects of the visual environment are important for this oriented behavior. The visual acuity of *P. hastatus* as measured by Suthers (*4*) lies between 0.7° and 3.0°. This visual acuity would allow the bats to distinguish from the release points such features of the terrain as the northern range of mountains in which they live. The bats might conceivably use celestial cues, but some of the accurate headings shown in Fig. 1 were observed on moonless nights or under overcast skies.

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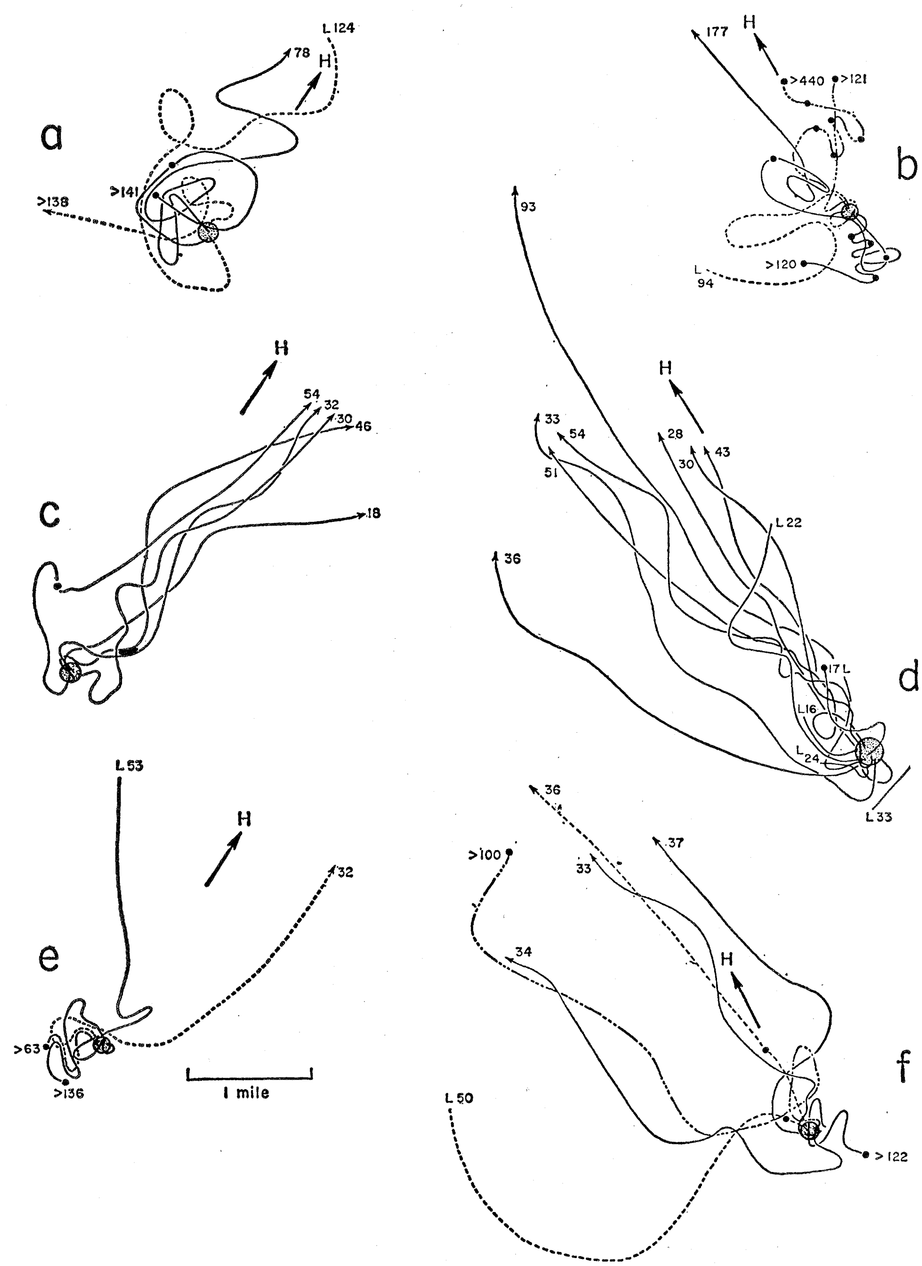

Fig. 1. Approximate flight paths of bats released 10 km from their home cave. Home direction is shown by *H*, release point by large circle, except for one bat in (d) released 0.5 km to the east. Parts (a) and (b) refer to blindfolded bats, (c) and (d) to bats without masks, (e) and (f) to bats equipped with goggles. In (a), (b), (e), and (f) solid lines mean bat returned with mask effectively in place, broken lines that mask was not effective on recovery, and lines containing both dashes and dots refer to bats not recovered at all. Numbers at the end of each line give the elapsed time in minutes from time of release until the signal was lost (> means experiment ended while signal still clear). Arrowheads signify gradual fading of the signal, and *L*, sudden loss of the signal.

References and Notes

1. T. C. Williams, J. M. Williams, D. R. Griffin, *Animal Behaviour* **14**, 468 (1966).
2. The transmitters were designed by W. W. Cochran ["Techniques in aerial telemetric studies of nocturnal migration of birds," Prog. Rep. 1, NSF grant GB-3155 (1965)], adapted for use on bats by P. Hartline, and built by the Electronics Laboratory of Rockefeller University. The receiver was constructed by S. Markusen, Esko, Minn.
3. G. V. T. Matthews, *Ibis* **103a**, 211 (1961).
4. R. Suthers, *Science* **152**, 1102 (1966).
5. We thank D. R. Griffin, J. Crane, the staff of the William Beebe Tropical Research Station of the New York Zoological Society in Trinidad, W.I., Robert Loregnard, and the Trinidad Government bat collectors under his supervision for assistance. Research supported by contract Nonr 4857 (00) between the Office of Naval Research and The Rockefeller University.

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Information Delivery and the Sensory Evoked Potential

Abstract. *The waveform of evoked responses recorded from human scalp is not determined solely by the physical eliciting stimulus, but also varies as a function of the effective information provided by the stimulus. There is a positive component whose latency is determined by the point in time at which ambiguity is reduced, and whose shape and amplitude are influenced by whether it is the presence or absence of an external event which delivers the information.*

We presented evidence (*1*) that the evoked potentials recorded from human scalp to simple stimuli, such as clicks or light flashes, are a function of the significance (*2*) of the stimuli to the subject. Responses to stimuli whose occurrence resolved some doubt or uncertainty were generally of larger amplitude and contained a positive-going process which reached peak amplitude at about 300 msec. This process was virtually absent when the occurrence of the stimulus did not resolve any uncertainty, that is, when the subject knew in advance which stimulus was to be presented next.

These and other findings (*1*) are con-