activity beginning as early as 20 to 25 msec was observed (C. Stevens and J. Miller, unpublished observations). This decrease in latency in the unanesthetized preparation has previously been noted; M. A. B. Brazier, in *Brain Mechanisms and Consciousness*, J. F. Delafresnaye, Ed. (Blackwell, Oxford, 1954); R. W. Doty, D. S. Kimura, G. J. Mogenson, *Exptl. Neurol.* **10**, 19 (1964).
11. W. C. Stebbins and J. M. Miller, *J. Exptl. Anal. Behav.* **7**, 309 (1964), Fig. 2 (F-Visual).
12. N. R. Bartlett and S. Macleod, *J. Opt. Soc. Am.* **44**, 306 (1954).
13. Supported by NIH grants MH 6722, 6M666.

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Telemetry of Homing Behavior by the Deermouse, Peromyscus

Abstract. *Miniature transmitters (weighing 2.5 to 2.7 grams, including encapsulation) implanted subcutaneously in deermice* (Peromyscus) *radiate a pulsed signal at 27 megacycles per second which can be detected by a simple antenna at a distance of 45 meters. The radio signal indicates movements of the deermice, periods of activity, and the location of occupied nests. One mouse was traced as it returned to its nest 300 meters in 1 hour. This rate of homing is many times more rapid than the rate usually determined by conventional methods for tracking small terrestrial mammals.*

The homing behavior of mice has been studied by repeated capture of the animals in live traps on their return to home ranges from release points in areas unfamiliar to them (*1*). But nocturnal mice usually enter the traps only at night, and may spend one or more days in the home area without entering available traps. In general, the maximum speed of homing, determined by the time between release and recapture, is only about 30 meters per hour from distances up to 1000 m or more (*2*). Since mice can travel at a much faster rate, the low measured homing speed could reflect extensive exploratory searching in the homing behavior. A few examples of homing at rates of 30 m per minute (*3*) suggest that mice may be able to navigate homeward in a manner analogous to that of homing pigeons (*4*). However, the paths taken by mice of the genus *Peromyscus* within 60 m of the release point, determined by trapping or visual observation, show no homeward direction (*1*). We have developed a radio transmitter small enough to be carried by a mouse to determine both the maximum speed of homing and all or most of the route taken.

Radio transmitters have been used to track wildlife and telemeter physiological data from unrestrained animals (*5*), but with transmitters too large for mice. Our transmitter (Fig. 1*a*) provides a pulsed radio frequency signal at about 27 Mc/sec. Its Hartley oscillator circuit is sensitive to temperature, and the components for each circuit must be matched with great care to the individual transistor and tested at the subcutaneous temperature of mice 34°C. Our transmitters oscillate at all subcutaneous temperatures but not at or below 25°C; thus they work only in a living mouse. Rise in subcutaneous temperature caused by increased activity of the mouse or by its change in position in an insulating nest increases the frequency of the signal but does not notably alter the repetition rate of the pulses. The repetition rate, which can be adjusted by critical choice of values for R_1, R_2, and C_3 (Fig. 1*a*), serves to identify each transmitter (*6*). The radiated power is delivered from the circuit as a whole, principally from the coil *L*. The radiation pattern is directional, so that small movements of the animal carrying the transmitter effect changes of signal strength at the receiver. The weight of the transmitter is 2.2 g when constructed with the smallest commercial components (Fig. 2*a*); addition of a silicone rubber covering increases the weight

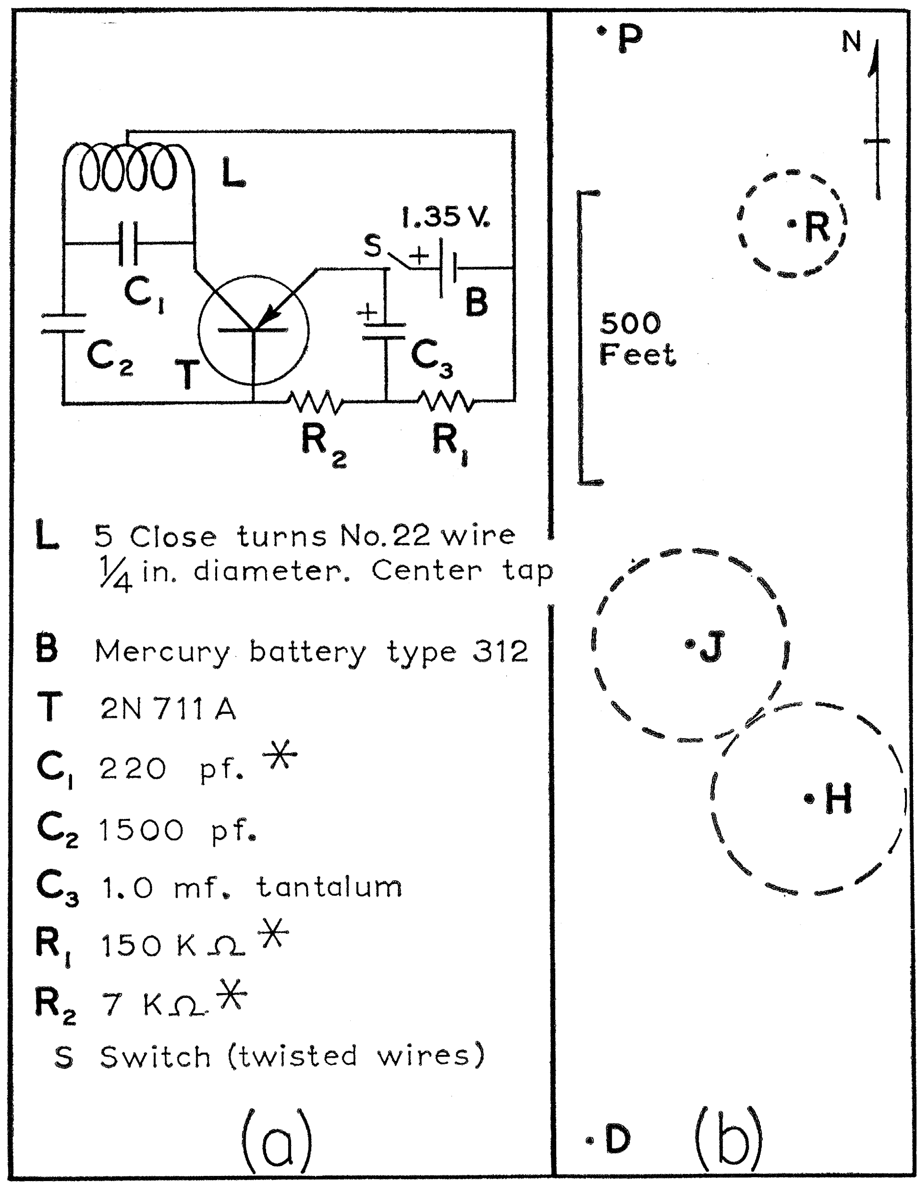

Fig. 1. (*a*) Schematic circuit of the transmitter. Ferrite chips are placed within the coil *L* for final radio-frequency tuning. Values marked * are typical and must be adjusted for each circuit (pf, picofarad; mf, microfarad; kΩ, 10^3 ohms). (*b*) Map relating release points to home (*H*) for the homing experiments described. Dashed circles show the approximate ranges of the receiver antennas (500 feet is equivalent to 152 meters).

to 2.5 to 2.7 g—about 10 percent of the weight of an adult *Peromyscus*.

A mouse was anesthetized with Nembutal, and the transmitter was implanted, without causing any bleeding, beneath the skin in a mid-dorsal position extending from the low-thoracic through the lumbar region. A small tube containing contacts for switching on the transmitter projected from the anterior end of the incision. With the transmitter so located (Fig. 2*b*), the mouse did not chew the incision. Observation of mice both in the laboratory and in the field showed that the transmitters caused no difficulty in locomotion; the mice climbed trees and moved through dense vegetation in much the same way as normal mice and kept their fur well groomed.

The deermouse, *P. maniculatus gracilis*, was used for homing studies in the field (*7*). An adult male mouse was first released at point *D* (Fig. 1*b*), 200 m southwest of its nest at *H*. It returned home and was caught in a trap near *H* during the following night. After implantation of a transmitter (Fig. 2*b*), the mouse was kept in the laboratory for 3 days (*8*). With the transmitter turned on at 1630, 11 August 1964, the mouse was transported to point *R* in a closed container and released there, 300 m north of *H*, at 2310 (Fig. 1*b*). The signal monitored with a portable receiver showed that the mouse moved about the release point but remained within 22 to 30 m (the range of the small whip antenna used) of *R* until 2348 when radio contact was lost. A vertical half-wave-length dipole antenna was used to pick up the signal at *H*. Another half-wave-length antenna at *J* was connected to the receiver at *H* by coaxial cable. The range of each antenna was 45 to 60 m. At 0045 on 12 August a strong signal came through the antenna at *H*; we switched to the *J* antenna where the signal increased in intensity. Our records indicate that the mouse first approached location *H* and then moved toward *J*; we may have missed an earlier signal at *J* because that antenna was monitored only at 10-minute intervals. The mouse spent the next 4 hours moving within the ranges of the two antennas and occasionally leaving the ranges of both. The nest was quickly located next morning in the base of a tree and only 5 m from the live trap in which this mouse had most frequently been caught. It was not trapped on the night of its homing, although traps were set nearby. Hence the actual homing speed of 300 m in 1 hour greatly exceeds the speed that would have been inferred from the mouse entering a trap on the following night.

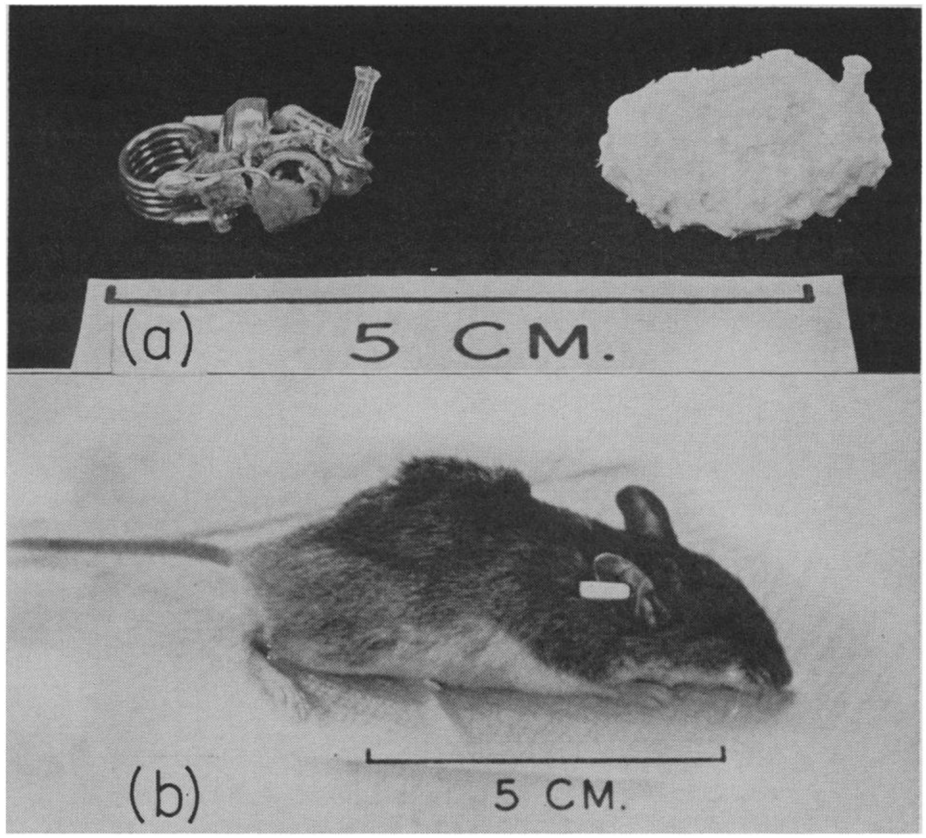

Fig. 2. Radio transmitter for mice. (*a*) Before and after encapsulation in white silicone rubber. (*b*) After implantation in a mouse, showing the deformation of the dorsal contour. The photograph is of an anesthetized animal immediately after the operation; the mouse carries a numbered metal ear tag.

A transmitter was similarly implanted in an adult female *Peromyscus* captured near *H*. The mouse, naive to homing experiments, was released at *P* (Fig. 1*b*), left the range of the whip antenna at *P* after 29 minutes, but failed to return to *H*. It was located the following day by its signal, 36 m from *P* and more than 3.5 m above ground within the hollow trunk of an upright dead tree. The mouse stayed close to this retreat during a subsequent period approaching the 3-day life of the transmitter battery. The last recorded radio-frequency and pulse-repetition rates were unchanged from values at the start of transmission (*9*).

In summary, conventional trapping was wholly inadequate to record the actual homing speed of at least one deermouse. Another mouse failed to leave the release point; it was not lost while traveling homeward. The stability in operation of the transmitter over a period of several days in the field, and the absence of detectable hindrance to the movements of mice, suggest that the actual paths taken by mice over longer distances can be defined, and that dimensions of the home range of an animal can be determined without the disturbance caused by repetitive trapping.

KENNETH S. RAWSON
PETER H. HARTLINE

Biology Department,
Swarthmore College,
Swarthmore, Pennsylvania

References and Notes

1. J. V. Griffo, Jr., *Amer. Midland Naturalist* **65**, 257 (1961); M. Murie, *J. Mammal.* **44**, 338 (1963).
2. P. M. Hacker and H. S. Pearson, *J. Linnean Soc. London Zool.* **42**, 1 (1951); O. J. Murie and A. Murie, *J. Mammal.* **12**, 200 (1931); **13**, 78 (1932); B. Schmid, *Z. Vergleich. Physiol.* **23**, 592 (1936).
3. W. M. Schleidt, *Z. Tierpsychol.* **8**, 132 (1951).
4. G. Kramer, *Ibis* **94**, 265 (1952); **99**, 196 (1957); G. V. T. Matthews, *Bird Navigation* (Cambridge Univ. Press, London, 1955).
5. W. W. Cochran and R. D. Lord, *J. Wildlife Management* **27**, 9 (1963); C. J. Sperry, Jr., C. P. Gadsden, C. Rodriguez, L. M. N. Bach, *Science* **134**, 1423 (1961).
6. We used repetition rates ranging from 3 to 230 pulses per second. Pulse durations were adjusted to 1/10 to 1/20 of the interval between pulses.
7. Field research facilities at Hancock, N.H., were made available to Harvard University by the kindness of Dr. and Mrs. C. F. Walcott. The study area was a level second-growth woodlot extending at least 300 meters in all directions from release points *R* and *P* (Fig. 1*b*).
8. Other mice with implanted transmitters were

lost to raccoons which repeatedly raided the live traps.

9. The radio frequency of the transmitters varied less than 200 kc/sec after implantation. Our receiver was a Commaire PT-27, Vocaline Co., Old Saybrook, Conn. (nominal sensitivity 0.1 μv increased with a 6-db gain preamplifier).

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Luminous Figures: Factors Affecting the Reporting of Disappearances

Abstract. *Subjects fixated luminous figures in darkness and reported the parts, either points or lines, that disappeared. After carefully controlled instructions, almost half of the disappearances were of lines and less than 20 percent were of fixation points, thus refuting the argument that meaningful disappearances are artifacts of the manner of fixation.*

The extent of the influence of past experience upon perception is one of the classical psychological problems that continues to pose intriguing questions. Recently, McKinney (*1*) suggested a very simple new technique for studying some aspects of this problem.

When a person fixates on a luminous figure in a darkened room, the figure appears to fragment, with parts disappearing and reappearing rapidly. In his initial report of this effect, McKinney stated that whole lines tended to drop away, leaving meaningful perceptual units intact. One luminous figure, for example, included the letters "*HB*." When fixating on this design, some subjects reported that lines dropped away leaving only the letter *H*, then the letter *B*, or the number *3*, or the number *13*.

This result, so comparable to earlier outcomes with stabilized retinal images (*2*), was interpreted as a demonstration of the influence of past experience upon perceptual organization (*3*).

Such claims were disputed by Hart (*4*), however, who recorded the verbal reports of subjects as they viewed luminous figures like those illustrated in Fig. 1. He found that line disappearances constituted only a relatively small proportion of the total disappearances, and that usually the part which faded from sight was the viewer's fixation point. Because of this relation between the disappearance of a part and the point of fixation, Hart (*4*) concluded that the meaningfulness of fragmentation is probably due to the meaningful way a subject scans and fixates the design rather than to anything inherent in the perceptual process itself.

Upon our request, Hart sent us his raw data and a complete description of his procedure. Unfortunately, certain aspects of his method make an evaluation of his data difficult, since an opportunity for bias occurred in the instructions repeated to each subject before presentation of the test figure. Even though the comparison between disappearances of lines and points was crucial in Hart's study, these instructions contained the word "point" nine times, but the word "line" was never mentioned. Moreover, it is possible that Hart's procedure favored the reporting of points in yet another way by providing the subject with a convenient letter "name" for each point in the test figure but failing to provide equally convenient labels for the lines.

In our first study, all details of Hart's procedure were duplicated, but the data failed to show the preponderance of fixation-point disappearances that was obtained by Hart. In the second study, the procedure was modified in an effort to eliminate any factors that might bias the reporting of disappearances toward either points or lines. This modified procedure about doubled the proportion of lines reported and, once again, failed to show a preponderance of fixation-point disappearances. Twelve naive undergraduate subjects were used in the duplication of Hart's fixation condition. The figures (Fig. 1) were made up of lines, 2.5 cm wide and 15 cm long, painted in luminous paint (Craftint Nite-Brite) on black display board. The subject viewed the luminous figure at a distance of 2.7 m in a darkened room, and his reports of fragmentations were collected by tape recorder. In a practice session, each subject was told to report "any changes" he noticed in the sample figure (Fig. 1*A*). During this session, the experimenter used only verbatim phrases from Hart's instructions for prompting and correcting the subject's report. These included instructions to keep from blinking or moving the head, to make reports continuous and complete, to report disappearances seen anywhere on the figure, to distinguish dimmings and disappearances but to refrain from reporting apparent movement.

The subjects then viewed each of the two test figures (Fig. 1, *B* and *C*) for three 2½-minute periods, with instructions to fixate on a different point, either *a*, *b*, or *c*, during the three periods with each figure. The Hart replication is called group *R*.

Twenty-four additional subjects (group *M*) viewed the Hart figures under modified conditions. In the practice session, 12 of these subjects were shown the luminous sample figure and also a schematic diagram of it in which the lines were labeled with numbers and the end points and the point of intersection with letters (see Fig. 1*A*). The experimenter explained to the subject that he was to report all disappearances as accurately as possible, but that, since changes occur quite rapidly, labels were provided to make reporting easier. The subject was instructed to report the disappearance of a line or point by saying the appropriate letter or number. If the midpoint of a line dropped away, he was to say "Mid-___," filling in the proper number. If the entire figure disappeared, he was to say "all." After these instructions, the experimenter pointed with equal frequency to the various lines and points of the sample figure until the subject responded quickly and smoothly and without referring to the schematic diagram. This approach guaranteed the subject a readily available name for each kind of disappearance in Hart's scoring categories before the testing session began.

The same procedure preceded the viewing of each test figure. Labels for the test figures corresponded to those in Fig. 1, *B* and *C*. An identical procedure was used for the remaining 12 subjects with the single exception that the points were labeled with numbers and the lines with letters. In all other respects, the original Hart conditions were duplicated for all 24 subjects in the modified replication.

For both test figures, the proportion of disappearances reported by each subject was calculated for fixation points, nonfixation points, lines, and the entire figure. In the upper part of Fig. 2 are presented the mean proportions for test figure *B* along with the comparable proportions calculated from Hart's original data; in the lower part are presented the same data for test figure *C*. All statistical comparisons cited in this paper were *t*-tests; the tests involving mean proportions were calculated by means of arcsin transformations.