AN ELECTRONIC APPARATUS FOR RECORDING MOVEMENT IN SMALL ANIMALS¹

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Several types of apparatus have been employed to record the movement of small animals. Other than those systems which require attached or embedded leads or the use of radioactive materials, most instruments are variations of the treadmill, such as a rotating annular cage (Kissel, 1963) or versions of the tambour stabilimeter, such as a transducer system (Davis and Ellison, 1964) or a magnetic pick-up device (Mitchell, 1959). Advantageous as these instruments are for recording general activity over long periods of time, they are not sensitive in differentiating relatively subtle changes in the type and extent of movement. A radar-like ultrasonic device (Peacock and Williams, 1962) overcomes any need for mechanical coupling between the animal and the recording system, but presents other problems of frequency interference and reflection, threshold determination, and vibration artifacts.

This paper describes an electronic apparatus based on capacitance sensing, for recording the movement of small animals. In contrast with the previous uses of capacitance sensing, such as the digital "on-off" recording of the presence of a snake on grids at various levels of a vertical cage (Kavanaugh and Norris, 1961) or the identification of mice wearing ferromagnetic collars (Kavanaugh, 1961), the present completely automatic system provides a linear recording of subject movement which permits the discrimination of the type of response made. The device was originally developed to record "freezing" be-

haviour of rats in a modified Miller learned-fear discrimination cage with Plexiglas walls and ceiling and grid floor. It may be used for long periods with any test chamber involving at least a metal grid floor with metal plate or cleaning tray beneath. The device requires no direct visual observation, places no restriction on the animals' activity, requires no special alteration of the experimental cage (*e.g.*, tambour mounts or photoelectric cells), and can be regulated to the size of the chamber, to the size of individual subjects, and to the magnitude of the movement to be recorded. It is convenient and simple to operate, and easy to assemble from components costing approximately \$80.00.

The system consists of the following units: (1) the animal test chamber; (2) oscillator; (3) master control panel; and (4) graphic recorder. Figure 1 presents a block diagram of the functional connection of these units, and Fig. 2, 3, and 4 illustrate in schematic form the electrical details of the circuits.

The grid floor of the experimental chamber and the metal catch tray beneath each form a plate of a relatively simple air dielectric capacitor, the capacitance value of which is a function of the size and shape of the grid. When a rat is introduced, it becomes a movable plate, parallel to the others, capable of modifying the ambient capacitance. The system represented in the block diagram consists of a 10.7 Mc/sec high-frequency oscillator whose output signal is fed into a se-

Fig. 1. Block diagram of the functional connection of units.

¹The development of this apparatus was supported by Grant No. 30 of the Ontario Mental Health Foundation. The author is indebted to J. T. Hawkins for technical assistance, and to W. J. Sarjeant and members of the Department of Physics for advice and circuit design. Reprints may be obtained from the author, Dept. of Psychology, Middlesex College, University of Western Ontario, London, Ontario, Canada.

Fig. 2. Diagram of the oscillator unit.

lecting network which produces a dc output voltage. This voltage is proportional theoretically to the change in the capacitance of the system connected between the input jacks. For example, one side of the oscillator is grounded to the test chamber, *i.e.*, the metal catch tray, and the other connected to the chamber's grid floor which is insulated from the rest of the cage. Then, with the sensitivity on the master control adjusted to the size of the animal, the subject's movement, in terms of fluctuations in capacitance, is displayed on a self-balancing potentiometric recorder as a distinctive wave form.

With the Heath Servo Recorder EUW-20A (8 in./min) set to mid-scale by "zero adjust", the system can be regulated to record fore-*vs* hind-foot movement, head movement, washing behaviour, and "freezing". If, as can be seen in Fig. 5, a rat rears to its hind-feet, capacitance changes and the frequency of the oscillator changes sharply causing the selective network to produce an output voltage. This voltage activates the recorder pen to deflect in one direction. Similarly, as can also be seen in the sample record, the animal

causes the pen to move back across the chart mid-line by lowering to four feet. Nonmovement, or "freezing", is revealed in the relatively constant and unvarying deflections on either side of the zero position depending on whether the animal remains still on two or four feet. The record also demonstrates two head movements as small, characteristic "blips". Washing behavior, which is not shown on this sample, appears as rapid fluctuations in pen activity. Since the rat on the grid is in parallel with the catch tray beneath, movements anywhere on the grid lead to the same pen deflections. Certainly the sensitivity of the master control must be adjusted for animals of different sizes, since large rats making small movements might produce the same pen deflection as a smaller rat making a large movement. Our method of calibration to permit quantification of the amount of an activity across animals involves the equating of the response amplitudes caused by two-foot rearing. Thus the recorder pen excursion for a common explorative response is adjusted to be the same in animals of different sizes. With the amplitude of the response kept relatively

Fig. 3. Diagram of the power supply unit.

Fig. 4. Diagram of the master control panel.

constant, the duration of a characteristic wave form is measured easily. However, with the amplitude of the response kept relatively constant, the characteristic wave form of specific movements is easy to recognize.

The apparatus has exceptional inter- and intra-unit electronic stability. Except for the occasional tube failure, little affects the operation of the system since other active elements are solid-state. As can be seen in Fig. 4, simple integrator networks, consisting of capacitors which may be switched across the recorder inputs, aid in integrating the response curves and reducing unwanted fluctuations. Other components of the master control panel are amplitude, signal discrimination, and recorder position circuits, and meters for monitoring voltage and recorder pen activity. It should be noted that the travel time for the pen in a full scale deflection, for the Heath recorder employed, is approximately 1 sec. Since the recovery time of the oscillator unit is zero, any dead time is a function of the recording

unit. If a dead time of less than 0.5 sec is needed, a servo recorder unit with faster response time would be required.

It is possible to record from many units by duplicating the master control panel circuitry and the oscillator component. If oscillators of the same frequency are employed, the test chambers must be shielded to prevent "broadcasting". It should be noted that leads from the test chamber to the oscillator must be as short as possible (approximately 6 in.) in order to minimize stray capacitance and hence increase the sensitivity of the system. In current experiments employing ac shock as noxious stimulation, it was also necessary to use telephone relays with light contacts on the shock leads at the test chamber and a heavier relay on the input leads to a shock scrambler (Foringer) to prevent a high capacitance developing. A 32-pole shorting relay was employed to disconnect the grids from the movement detector during shock. This altering of capacitance allowed the graphic recording of

Fig. 5. Sample recording.

shock onset and duration by causing the recorder pen to deflect off scale.

The apparatus is giving reliable recordings of activity in our avoidance-escape learning experiments, and undoubtedly has an application in the recording of activity cycles in physiological and metabolic studies, in psychopharmacological studies (e.g., Bindra and Anchel, 1963), and in ethological investigations.

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