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# APPARATUS

## THE CONTINUOUS MEASUREMENT OF STRENGTH OF PULL BY RATS

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In the investigation of motivation in rats, various indexes of the strength of motives have been utilized. Among these are the frequency with which the rat crosses a charged grid, the speed of digging through obstructing shavings or sand, the rate of bar-pressing, the rate of string-pulling, and the speed of running. One obvious index, which has not yet been explored thoroughly, is the effort exerted by a rat in pulling against a restraining force in order to reach its goal. An apparatus designed for the measurement of this effort is described here.[1]

The influence of a large number of variables on the strength of motivation (using strength of pull as the indicator) may be studied with the aid of this device. Examples are: (1) kind and strength of need; (2) desirability of goal object; (3) distance to the goal; (4) effects of past experience in the situation, in conjunction with the more momentary influences; (5) speed with which the animal is permitted to progress; (6) amount of resistance to be overcome before locomotion is possible; and (7) the structure of the pathway. A simplified sketch of the instrument is presented in Fig. 1.

*Runway.* The alley traversed by the rate may be of various types; Fig 1 shows merely the kind we have used. It is constructed of two 6-ft. sections ($S_1$ and $S_2$) with 3-in. sides and 4-in. floor, painted white inside and covered with a wire screen. To give the rats good footing, ¼-in. wire mesh was stapled to the floor. This was done before the sides of the run-way were attached, hence the floor was uniformly and smoothly covered. The starting-box is 1 ft. long and is separated from the rest of the run-way by a guillotine-gate, string-operated by *E*. The food-box (F) is 18 in. long and is entered through a light 'push-up' door.

*Polygraph.* The polygraph is shown at the left in Fig. 1. It was built to carry wide paper. The speed at which the paper passed was varied by means of gear shifts. About 2 in. above the paper there is a horizontal iron bracket on which is mounted the writing-arm ($W_1$). This arm moves on a hub (H) to which there is attached beneath an horizontal bakelite disk. A sector ($C_2$) of this disk is covered with thin sheet brass. Over the bakelite disk and this brass sector moves a spring tongue ($C_1$) that is attached to the long side of the writing-arm. This tongue (slider) makes contact with the brass sector (slider contact) and closes the circuit to the motor (M) when the writing-arm is moved. A pulley block ($P_3$) is attached to the end of the long side of the writing-arm. A long, light coil-spring is fastened to the pulley and through the pulley is run the fish-line leash (L) that is attached to the rat.

*Drum and accessories.* The drum, to which the other end of the fish-line leash

[1] This apparatus was built at Swarthmore College.

(L) is attached, is driven by the constant-speed motor (M) by means of a matched pair of speed-reducer pulleys (P$_1$ and P$_2$). At the free end of the drum there is a metal pin (shorted through the drum-mounting) which closes the battery-circuit to the revolution-marked (W$_2$) on the polygraph whenever it touches the spring-brass contact (C$_3$). To permit rewinding of the fish-line leash after a run, the drum is mounted on a hinged base which may be tilted back toward the motor pulleys,

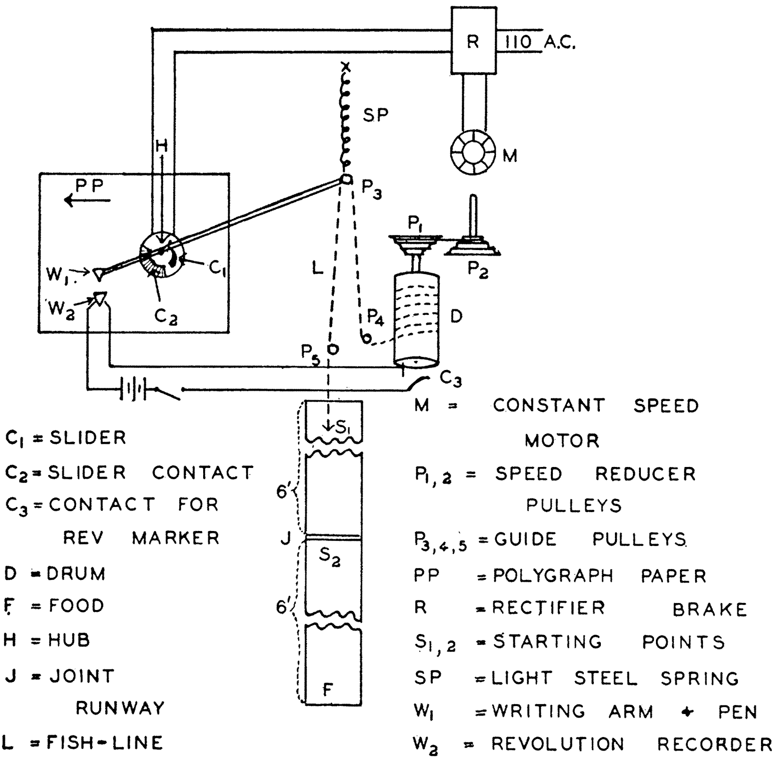


FIG. 1. SIMPLIFIED SKETCH OF THE APPARATUS

thus loosening the drive belt. The rectifier (R) is so constructed that a direct current passes through the motor when the tongue-slider (C$_1$) on the writing-arm and the slider-contact (C$_2$) on the bakelite disk do not touch. This acts as a brake on the motor and prevents any coasting of the drum.

*Writing-arm.* The writing-arm, a ¼-in. aluminum rod (see Fig. 2) is made in two sections both threaded into the center hub (H) which turns on the shaft (SH). The short section of this arm, 4 in. in length, carries the recording-pen (W$_1$); the long section, 16 in. in length, carries the slider-tongue (C$_1$) and the pulley block (P$_3$). The slider-tongue, made of spring-brass, is fastened to the long lever-arm by means of the block (BL). It is shaped so that it touches the bakelite plate (PL) and makes contact with $C_2$ when the writing arm is turned. Small rubber-covered wires led from $C_1$ and $C_2$ to the motor and complete the circuit whenever those poles are brought into contact.

*Revolution-marker.* Every revolution of the drum is recorded on the polygraph by means of a device made from an ordinary door-bell. The breaker mechanism of the bell was removed so that only the make and break of the electrical circuit moved the buzzer arm. On this arm a recording-pen ($W_2$) is fastened. This device was mounted on a bakelite plate and clamped into position on the polygraph where the two recording-pens ($W_1$ and $W_2$) would be in perfect alignment.

*Recording-pens.* The pens used on the polygraph ($W_1$ and $W_2$) were Wrico No. 7. They ride vertically in 1-in. holders made of brass tubing, the internal diameter of which was slightly larger than that of the pens. The pens could consequently

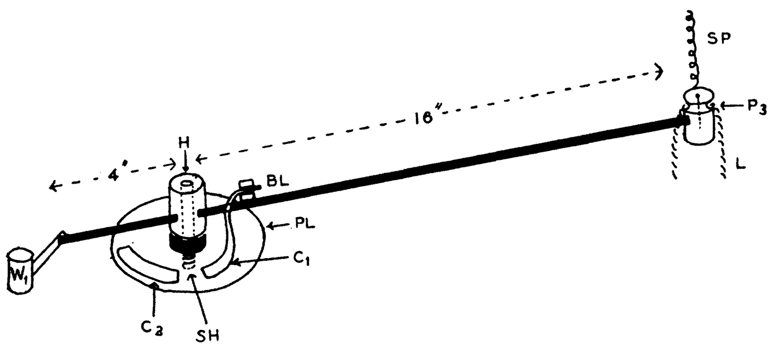


FIG. 2. WRITING ARM

move freely in the vertical direction which allowed for irregularities in the paper-surface.

*Harness for the rat.* A harness must be made specially for every experimental animal. As it is fairly difficult to construct a harness that will stay on a rat for any length of time without irritating its skin, we shall describe in detail the construction of the tape-and-chamois harness that we have found to be the most successful.

An H-shaped piece of chamois is cut with one side of the H—the side that goes around the chest of the animal—a little longer than the other. Over the cross-bar of the H is slipped an ordinary paper clip by means of which the leash is attached to the harness. After the clip is in place the chamois is covered with strips of adhesive tape cut to width and length. The tape is placed on both sides of the cross bar but only on the external side of the rest of the harness. Holes are then punched in the ends of the strips and short pieces of fish-line drawn through them. The harness is then ready to be placed on the rat. This is best done when the animal is lightly etherized.

A leather leash which runs behind between the rat's legs is attached to the paper clip that is on the belly band at the cross-bar of the H. This point of attachment proves more satisfactory than the shoulders. The fish-line leash which ran to the drum was fastened in turn to the leather leash.

*Spring.* The spring (SP), Figs. 1 and 2, was closely wound from No. 32 spring wire. It is ½ in. in diameter and, unstretched, 12 in. long. This strength of spring permits long extension with relatively small amounts of effort.

*Motor.* The motor (M) that we used was manufactured by the Bodine Company. Its rating is 1,600 r.p.m., 1/400 horse power, 60-cycle, shaded-pole induction, reduction gear ration of 17-1. A more powerful motor is desirable.

*Rectifier.* The wiring diagram of the rectifier, (R), is shown in Fig. 3.[2] The operating switch (OS) is the contact ($C_1$ and $C_2$) in Fig. 1. The power switch (PS) was so located that the filament heating transformer (FHT) operated con-

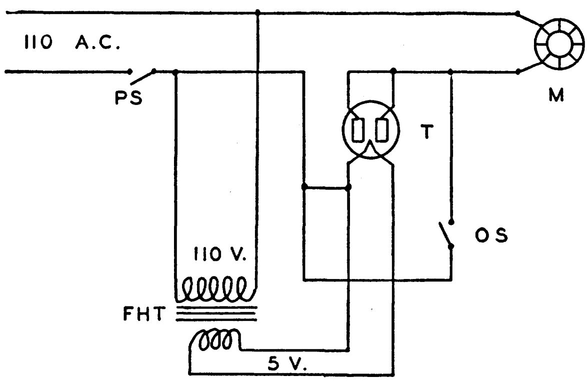


FIG. 3. WIRING DIAGRAM OF THE RECTIFIER

tinuously through the course of a day's experiments. The tube (T) was a Cunningham 83V. In operation, the rectifier passed 110 v. A.C. straight to the motor when the operating switch (OP) was closed; if that switch was open the tube was in series and it passed a pulsating 5 v. D.C. to the motor.

*The course of a run.* In order to show how the various parts of the apparatus function it may be well to trace the sequence of events in a sample run. At the beginning of the run the writing-arm, held by the spring, is in its resting position (Fig. 1). The rat begins to move and the line feeds through pulley $P_3$. Since the drum is motionless, the pulley moves and stretches the long steel spring, turning the writing-arm horizontally. After a certain minimum displacement the slider ($C_1$) touches the semi-circular contact ($C_2$) thus starting the motor. Thereafter, so long as the animal moves as fast as the line is released, the motor will keep on turning. If he slows down, or stops, he then serves as a fixed point, the drum releases more line, and pulley $P_3$ (and the writing-arm of which it is a part) moves back toward its resting point until the circuit through the slider is broken and the motor stops. As long as the rat keeps pulling, the line is released from the drum at a constant rate. The faster he moves, the more he stretches the spring. The displacement of the recording pen thus indicates in a continuous manner how much the spring is stretched as the rat moves toward food. The unit of measurement most

[2] The rectifier was designed by Dr. Edwin B. Newman to fill the need for a braking device.

easily used with the present arrangement is the average strength of pull during each separate revolution of the drum, the revolutions being recorded by the marker circuit through the contacts on the drum and its base.

*Training procedure.* Because pulling is a new and strange activity for rats, preliminary training must be carried on until they are adapted to the situation. Lunging is characteristically the first response. After a relatively small number of trials, however, the animals settle down to reasonably steady pulling and almost no retracing. A training series finally found to work with black rats about 100-105 days old was the following: two days of three *free* runs each; three days of unrecorded *pulling* trials, two the first day, three the second, and five the third. Then recorded runs may be made, although more practice trials may be necessary, depending upon the temper of the animals. It is necessary to use moderate motivation during the adaptation period, in order to avoid the extreme lunging which tends to occur in very hungry animals. Practice should be planned with a view to the later experimental

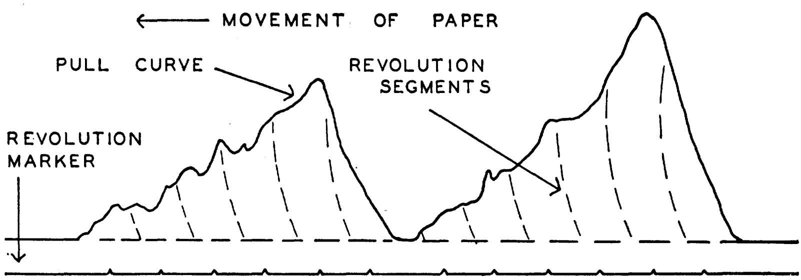


FIG. 4. A SAMPLE RECORD

procedure. Individual caging is necessary and care must be taken that the animals are not weakened so that they are incapable of pulling strongly.

*Analysis of records.* A curve of an animal's pull for one run can be split into segments corresponding to successive revolutions of the drum (see Fig. 4). This may be done by erecting arcs, like those described by the writing-arm, above the marks made by the revolution indicator. These arcs cross the ink record at a point corresponding to where the revolution-marker *would* have been if it had been moved also. Some sections of the record on the polygraph tape will show no displacement of the pen from the resting position, simply because the animal has stopped pulling. These 'blanks' may be disregarded and the actual successive revolutions of the drum during pulling, as indicated by the marker, used as a basis for computations. The areas of each of these segments can be determined with a planimeter. Each area is then divided by the length of the baseline unit as automatically marked off during *continuous* operation, the result being an average height of a segment of the curve during one revolution of the drum. This measure may be transmuted into the number of grams necessary to stretch the spring this average amount, by means of an empirical calibration of the whole instrument. In the latter procedure, a rough but workable measure may be reached by simply supporting different known weights over a pulley at the end of the line in the runway, letting the polygraph run with the motor-drum circuit broken. The displacements thus caused and recorded may be used in constructing a curve from which the average heights of experimentally obtained pull segments can be translated into grams.

A word should be said about the final part of the pull-record, when the recording-pen moves toward its point of rest because the rat has stopped at the food-box. Pulling, or at least forward movement, has ceased. It is possible to compute the point at which the animal actually reached food, but it would be better to utilize a treadle at the food-box door and an additional marker on the polygraph. Furthermore, treadles placed systematically throughout the runway would greatly assist in making analyses of the actual amount of work done.

Two corrections have been applied to individual records. The first is for certain defects in the apparatus. With the present set-up, as the rat pulls near his maximum, friction in the pulleys and other parts lessens the relative increase in amount of stretch of the spring. The rat does not, therefore, 'get credit' for all the work done. If the average height of a segment of the curve is translated on an empirical basis into the average number of grams pulled, as described above, the necessary correction is automatically made. The second correction is for weight of animals. It may be desirable to permit pull-values for lighter animals, which pull smaller absolute amounts, to have as much influence in the computations as values for heavier animals. The values for lighter rats may, therefore, be stepped up in proportion to the lack of weight. The desirability of this correction will depend upon the kind of experiment attempted.

The apparatus described, and the procedures as well, have been arrived at in large measure by way of trial-and-error. Particularly difficult to solve are such details as the proper length and tension of the spring, the proper motor-control, and the practical type of training-period. These details must be adapted to the kind of problem to be studied and animals to be used. Experience will suggest modifications of the whole apparatus to fit particular research needs.