TECHNICAL NOTE

A RAT LEVER WITH REMOTELY VARIABLE INERTIA¹

Petre, Albright, and Galloway (1967) have described an operandum, suitable for children and other animals of similar size, in which the force required to operate the lever is remotely variable. Current passed through an ordinary solenoid attached to the lever varies the inertia, and hence the force required to depress the lever. A similar system had been tried early in the development of the piece of apparatus described here. The principal reason for rejecting this method was that the plunger being drawn strongly against the inside walls of this type of solenoid produced excessive friction. It made specification of an inertia within acceptable limits of accuracy and in the range required for a rat (10 to 200 g) impossible.

Static friction, in the solenoid as well as between other moving parts, can be abolished by the use of a rotary solenoid of the kind made by Kuhnke, St. Johns Road, Penn, Bucks., England. This device has a spindle, which is mounted in ball races, and a smooth rotary action similar to that of an electric motor. A simple system based on this solenoid was used with success to schedule increasing force requirements for rats' pressing maintained by water reinforcement (Oatley, 1965).

Figure 1 shows a diagram of the present arrangement. The solenoid used is Kuhnke Type C 50, continuously rated at 24 v and 18 w, having a 25° rotary stroke. The maximum torque of the solenoid chosen is 4000 g cm at the end of its stroke, very much higher than required for this application. This allows the device to be run well below maximum capacity to prevent any substantial heating. Current through the solenoid may be controlled (as in an early version; Oatley, 1965) from a long series resistance wire with tapings at intervals switched by a uniselector, but this method, though simple, allows some temperature fluctuation, and requires the uniselector to switch relatively high currents. A simple transistor power amplifier, as shown in Fig. 1, approximates a constant current source, and allows the current specifying resistors in the base circuit of a transistor to be of small wattage. These are fixed resistors ranging from 12 K to 35 K-ohms with 1 to 5 K-ohm trimming potentiometers in series. These latter

Fig. 1. Circuit diagram and mechanical drawing of the varipress. The component labelled "coil" in the circuit is the rotary solenoid. In the mechanical diagram the letters refer as follows: A shutter, B photocell and photobeam, C counterweight, D stops, E rotary solenoid, F wall of rat box, G rat lever.

¹I am grateful to Messrs. J. Chambers and J. Allbut for advice during construction, and to Mr. D. A. Tonge for assistance during calibration and testing of this device. Some of this work was supported by the Medical Research Council. Reprints may be obtained from the author, Laboratory of Experimental Psychology, The University of Sussex, Brighton, England.

were mounted to be accessible to a screwdriver when the amplifier panel is in place on the equipment rack.

An initial source of trouble with this device was that the magnetic material used in the solenoid caused some torque to remain when the current was removed. This produced a hysteresis effect, with the torques for an ascending series of currents being substantially less than for a descending series. The difficulty was virtually abolished by briefly reversing the current through the solenoid as the uniselector moved to its next position. This was achieved with a relay as shown in the circuit diagram of Fig. 1.

The device was calibrated by hanging weights on the lever and measuring the current passing through the solenoid with a current meter, permanently in series with it, but not shown in the circuit diagram. It was of the utmost importance to adopt a standard procedure when making measurements, as small changes in pro-

cedure gave rise to rather large variations in the mass required to tip the lever, presumably due to small uncontrolled vibrations, the speed of loading the lever and so on.

The method finally used for measuring the weight requirement was to make coarse adjustments by putting balance weights in a small pan suspended from the bar, and making the fine determination by unwinding from a spindle on to the pan, a calibrated Meccano chain. The weight recorded was that which just tipped the lever.

The weight-against-current curve for the lever is plotted in Fig. 2. Each point represents a mean of 12 readings, and the range is given by the vertical bars. These readings included sets made in which 30 sec were allowed to elapse between successive depressions of the lever, as well as with determinations made immediately after pressing it. This was because Petre et al. (1967) reported that with their device the torque increased with the time since the last lever press. This occurred only to a trivial extent using this type of solenoid. A series of readings was also taken after the amplifier had been left switched on for 3 hr. Overall repeatability was of the order of 5% but readings in a given upward or downward sequence had a very much smaller range (of the order of 2%).

Changes due to heating did not seem to be obtrusive; readings taken after leaving the device for several minutes with maximum current passing were also within the range shown in Fig. 2.

The device in the present and previous versions has now been in use for several years and many thousands of lever presses have been made by rats in schedules of increasing force requirement. It would be equally suitable for use in an adjusting schedule.

KEITH OATLEY
University of Sussex

Fig. 2. Mean weight and range (vertical bars) required to tip the lever as a function of uniselector position and solenoid current in milliamps.

REFERENCES

Oatley, K. *Thirst and drinking mechanisms in the regulation of water intake in rats*. Unpublished Ph.D. thesis, 1965, University of London.
Petre, R. D., Allbright, J. D., and Galloway, C. A remote controlled force operandum. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 149-150.