
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

OPERANT CONDITIONING AS A TECHNIQUE FOR THE SOLUTION OF PRACTICAL PROBLEMS IN ANIMAL HUSBANDRY

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Most operant conditioning studies published so far have dealt with small animals (Ferster and Skinner, 1957) and the problems investigated have been of an academic nature. It is the object of this paper to show that the well established principles of operant conditioning apply to the dairy cow and the technique can be used for the solution of practical problems.

Establishing an operant response involves inducing an animal to "emit" an action which may be rewarded (positive conditioning) or reduce discomfort (negative conditioning). If the water supply in a rat's cage can be turned on by depressing a bar, a thirsty rat will quickly learn how to get a drink. The learning process called "shaping" may be accelerated if the experimenter turns on the water each time the rat passes near to the water dish and bar (which is called a "manipulandum"). This conditioned response will remain so long as it is "reinforced" by a reward from time to time. However, it will be "extinguished" if not reinforced.

The manipulandum in equipment designed for use with rodents is usually a bar which can be operated by a paw. However, a cow does not use her feet in an exploratory situation but tends rather to use her nose. For this reason a "nuzzle plate" has been adopted as the standard manipulandum. This has taken the form of a PVC plate fixed to a steel rod which operates either a micro-switch or a small pneumatic valve. The first equipment used involved solid state electronics but in order to have equipment which is "hose proof" pneumatic logic has been introduced because of its suitability under cowshed conditions. Essentially the apparatus consists of an input, the "manipulandum", by which the animal communicates with the system and a programming device which relates the input to the output. In the Ruakura equipment, the output consists of a belt-driven feed dispenser which provides the animal with a limited amount of highly palatable concentrate (80% crushed barley, 20% corn meal, Moore *et al.*, 1974).

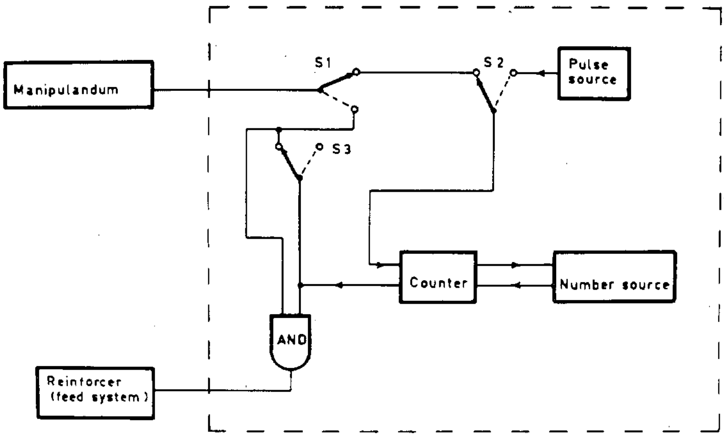

FIG. 1: *Schematic representation of an operant conditioning unit.*

There are three units within the control system; a counter, a source of numbers, and a source of time intervals. Figure 1 shows a schematic diagram of an operant conditioning unit which applies to both the electronic and pneumatic systems in use at Ruakura. The changeover from ratio to interval based programmes is symbolized by the multiple switch S1,2,3. In the switch position shown by the full lines in the figure, the apparatus is set up for ratio schedules while the dotted lines indicate connections for interval based schedules. Thus four types of schedule are possible with the system:

(1) Fixed ratio (FR) in which the animal is reinforced by a reward delivered after operating the manipulandum a fixed number of times.

(2) Variable ratio (VR) in which the animal is rewarded according to a schedule in which the ratio varies randomly about a mean.

(3) Fixed interval (FI) when the reward becomes available after a certain interval of time regardless of the frequency of operation of the manipulandum.

(4) Variable interval (VI) in which the interval varies randomly about a mean.

When operant conditioning is used as a general-purpose technique, the variable-interval schedule is perhaps the most useful.

Providing a reward in a random manner after the manipulation of an input will be seen to be the principal of the "one-armed bandit", the astonishing popularity of which demonstrates the effectiveness of the technique.

The evolution of operant conditioning equipment at Ruakura has finally led to the adoption of a pneumatic logic system based on the use of eight-hole punched tape which is read by a specially designed pneumatic reader. Details of the various systems are given in the appendix. Quite complex programmes can be punched on the tape so that the complexity of the equipment has been substantially reduced and the tape is available for use both with electronic or pneumatic equipment.

THE OPERANT RESPONSES OF THE DAIRY COW

In order to establish the responsiveness of the dairy cow to an operant schedule, seven Jersey cows aged 3 to 9 years were subjected to the four Skinnerean schedules outlined using a barley-cornmeal mix as the reinforcer. After the animals became familiar with the experimental chamber, they were subjected to shaping sessions at aproximately the same time each day for 20 to 35 minutes. Once shaping was completed, the cows were exposed successively to all four basic schedules and were advanced to a higher value schedule when the response pattern had reached set criteria. Responding was accepted as stable when the pattern of response over five sessions was similar to the responding during the previous five sessions so that there were at least ten sessions in any one schedule.

The schedule used were as follows:

1. Fixed ratio ranging from FR 1 to FR 100.
2. Fixed interval ranging from FI 60 to FI 90, FI 120 and FI 180.
3. Variable ratio in which the means were 5, 20 and 40.
4. Variable interval with means of 45 and 90 seconds.

The number of sessions required for the shaping of the cows varied greatly, one animal requiring only one session while the slowest learner required 14. The average was 6.9.

Figure 2 sets out typical responses from the cows involved in the experiment. Under fixed ratio (FR) conditions the gradient increases with the ratio but above 20 there is little change. The post-reinforcement pause tends to increase with ratio. The fixed

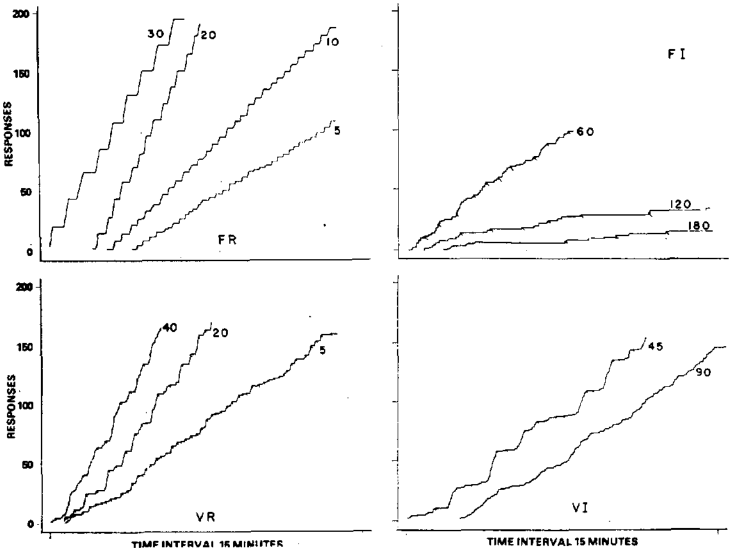

FIG. 2: *Representative cumulative records of cows under fixed ratio (FR), fixed interval (FI), variable ratio (VR), and variable interval (VI) schedules.*

interval (FI) study shows a rapid diminution in slope with increasing interval. The variable ratio (VR) schedules again show the slope as stabilizing at a ratio with a mean of above 20.

The responses typified by Fig. 2 correspond with those to be found in the literature for small animals and demonstrate that the dairy cow fits into the accepted pattern of operant conditioning.

THE APPLICATION OF OPERANT CONDITIONING TO THE SOLUTION OF A PRACTICAL PROBLEM

The problem was to discover the point at which a dairy cow could detect an electric leakage applied to the teats, the rump or the chest. This is an important question in cowsheds where electrical leakages occur (Whittlestone *et al.*, 1975). The problem was chosen because it seemed possible to solve it by the use of a simple operant conditioning technique using two manipulanda (Whittlestone and Cate, 1973). Two nuzzle plates were fitted on either side of the feed bowl (Whittlestone and Cate, 1973) and each connected to the same source of random numbers; thus the cow was rewarded with an equal probability on both sides. One plate was connected to a relay which turned the current on and the other to a relay turning the current off. The animals were shaped to use one plate about 90% of the time. When the experiment started, this plate turned the current on. Suitable electrodes were fitted either to the teats, to the rump or to the chest and a 50 Hz current increased in steps of 0.5 mA within the range of 0 to 10 mA. Once the threshold was reached, the cow shifted to the use of the "10%" plate which turned the current off, showing a very marked change in the ratio of utilization of the two plates. The results showed that the threshold for a single teat was 7 mA, for four teats together, 6 mA, for the rump 6 mA and for the chest 4 mA. The consistency of the responses demonstrated the value of this technique for the solution of a problem in which the animal is presented with two choices.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to H. de Langen and D. H. B. McQueen for their assistance in the preparation of the figures.

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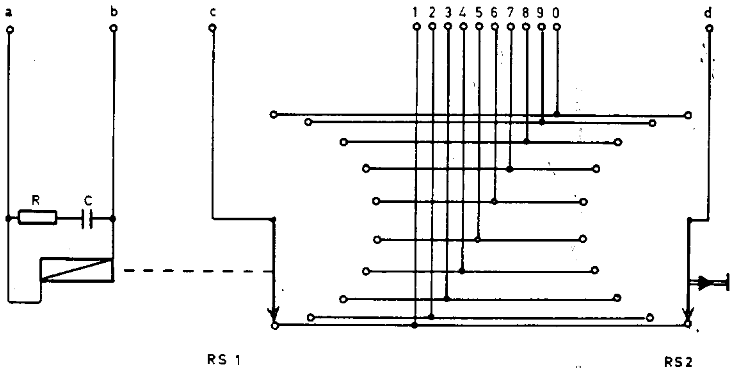
APPENDIX

Electric Counter and Number Source

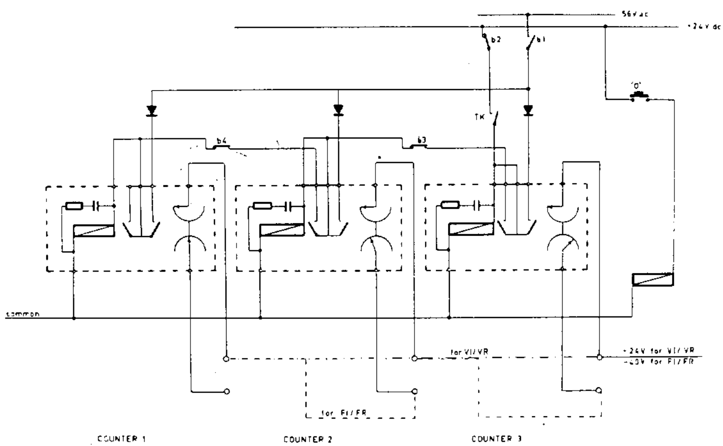
Fixed Ratio and Interval



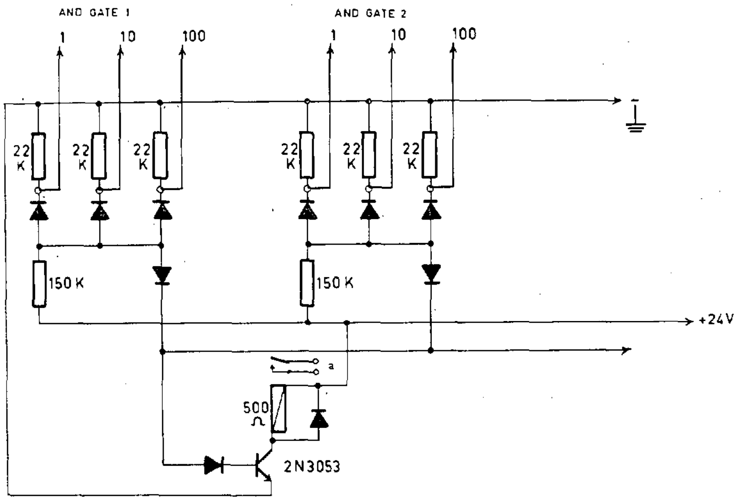
COUNTER CIRCUIT

Electro-magnetic Counter and Stepper Switch

Pulses reaching terminals a and b cause RS1 to step round. RS2 is set by a push-button. When RS1 coincides with RS2, terminals c and d are connected. The circuit below provides an output each time the preset number is reached and may be used for fixed ratio and interval.



Variable Ratio and Interval



The AND Gates used in the Random Number Source

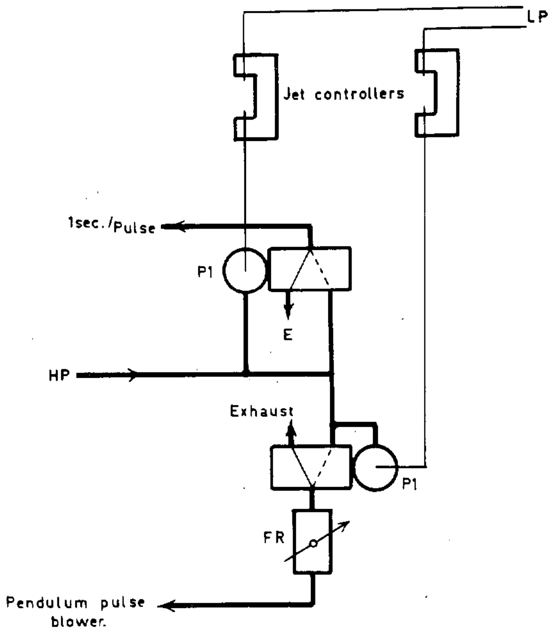
A set of 38 gates is used, the inputs corresponding to units, tens and hundreds connected to a 'patch board" which is set up with a series of random numbers. The device is connected to the counter system in the previous figure with the outputs corresponding to units, tens and hundreds connected to the appropriate terminals of the patch board. When the preset numbers are reached by the counters, the relay operates, energizing the reinforcing system (usually a feeder). This system is used for both VR and VI schedules.

Note: The pulse source for both V1 and F1 programs is a set of contacts driven by a synchronous motor to provide 1 Hz pulses.

PNEUMATIC CONTROL SYSTEM.

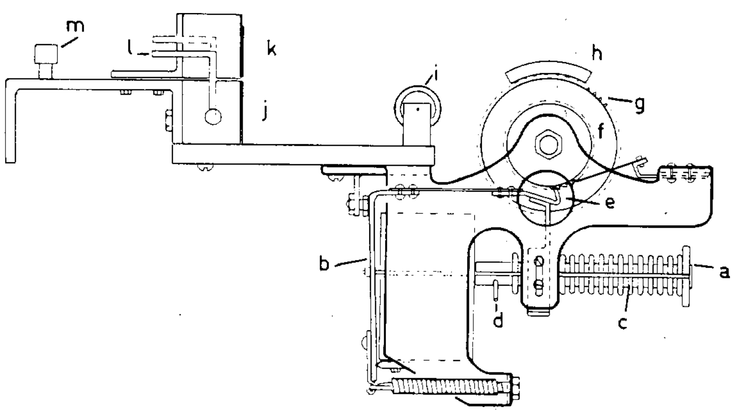
The Pulse Source

The pulse source is a "seconds" pendulum which is driven by appropriately timed puffs of air. These puffs are regulated by a "jet controller" which senses the arrival of the pendulum at the end of its stroke and operates a booster valve which turns on a puff of high-pressure air through a three-port valve and a restrictor. A jet controller placed at the centre of the pendulum's swing provides one second pulses for the control circuits.



The Tape Reader

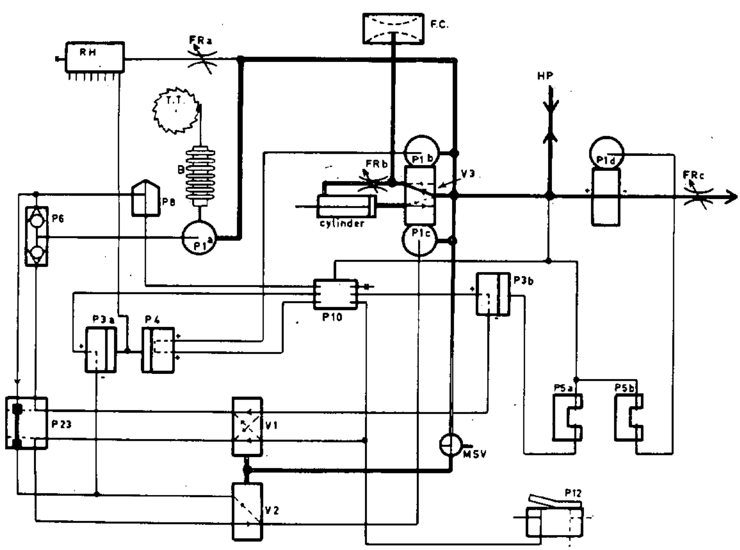
In this system the counter and number source are combined in the form of a pneumatically driven tape reader which detects holes in the tape. The drive is a modified telephone uni-selector switch in which the solenoid is replaced by a pressure-operated bellows system (a, b, c, d). The pawl (e) drives the toothed wheel (f), so rotating the drive drum (g) against which the tape is held by the guide (h). The tape is pulled between the blocks (j, k), the former being drilled with a series of holes corresponding to an eight-hole tape and fed with air at logic pressure from a manifold. The holes in (k) individually connect to a series of outlet tubes (l) connected to the pneumatic logic system.



The Logic Circuit

The two modes of operation, namely, fixed or variable interval, or fixed or variable ratio, are selected by the mode selection valve (MSV) controlling the five-port mode control valve (V1) and the three-port mode control valve (V2). The diagram shows the interval mode.

The pendulum driving system is shown in a simplified form as a single jet controller (P5b). The jet controller P5a represents the source of one second pulses which are fed to the normally off inverter P3b. The amplified pulses pass through V1 to the memory unit P23 and thence to the shuttle valve P6. They then reach booster P1a and so drive the bellows mechanism of the tape drive assembly, advancing the tape one hole per second. When a hole appears on the tape, a signal is fed to both P3a and a normally on inverter P4 of the feed control system. A signal appears on the output of P3a while the output of P4 drops to zero. The memory unit P23 turns off the pulses from the pendulum and so stops the tape drive. The memory unit action also couples the output from the manipulandum valve P12 which is transmitted via the mode control valve to the actuating booster P1c of the feed timing unit. Operation of the manipulandum now results in a signal applied to the feed timing cylinder and the release of feed into the bowl. The duration of feed flow is determined by the time taken by the control cylinder to reach the end of its stroke when the piston rod obstructs the proximity jet P8. This causes a signal to reverse the position of the memory unit and supply a pulse to the tape drive, so moving the tape on one hole. The signal from the tape reader drops to zero, causing a reversal of P3a and P4, so returning the feed timing cylinder to its original position. The tape continues to step on until another hole appears.



When used in the ratio mode the output of the pendulum is disconnected. The manipulandum output passes via V1, P23 and the shuttle valve P6 to the tape drive booster. The tape is thus stepped on with every operation of the manipulandum. The arrival of a hole in the tape operates P3a and P4 to bring about the feeding sequence and the moving on of the tape, so removing the tape reader signal.

The source of regular or random numbers for ratio or interval schedules is the punched tape so that the "counter" and "number source" referred to in Fig. 1 are in effect the combination of tape drive and punched tape.