A MACHINE WITH INSIGHT

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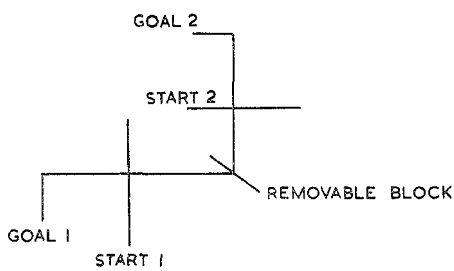
When an animal solves a novel problem without trial and error, a psychologist tends to call the behaviour insightful. A relatively simple machine resting on new principles, capable of this and learning, has been constructed by the writer in order to demonstrate his tentative explanation of this and other aspects of animal behaviour.

The machine consists of three parts. The first retains information and utilises it in accordance with the goal set. The second is a trolley which is guided by a pulse which the first part transmits; it also has bumpers which cause it reflexly to steer away from any obstacle and to turn out of corners by reversing one of the motors which drive each of the two main wheels separately; and it has a light mounted on it which is thrown forward at a wide angle. The third part comprises photocells, which act as receptors and are attached to the walls of the maze which the trolley is required to learn.

Behaviour

The machine's performance is more precisely described as follows. It learns and retains any two short, modified, rat mazes. On the learning run the machine is made to enter all the blind alleys of the maze on its way to the goal box. On the next run it will travel straight from the entrance of the maze to the goal box without entering a blind alley. If the two mazes, which it has learnt and retained, share a common point (even if this is down blind alleys in each maze), the machine will, on being set in an entrance, find its way without any further trial and error to whichever of the two goal boxes the demonstrator makes it seek. The machine appears to have this property in common with the rat, which suddenly integrates its past experience in accordance with its aim in the latent learning situation when a goal object is introduced.

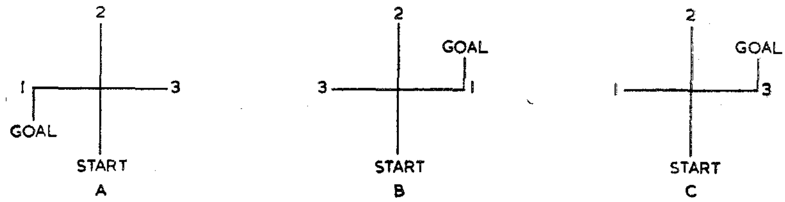
FIGURE 1



After learning two mazes separately, the machine will solve the problem of finding its way from the entrance of one maze to the goal of the other.

Furthermore, the machine can transfer or generalize its "knowledge" to mazes of completely different shape and similar only in a highly abstract way. Each alley in the maze is marked by a different signal which is supplied to the machine. If the sequential order of the signals down the alleys with respect to each other is kept the same, even though the shape of the maze is quite altered, the machine can still find its way. It will execute an errorless run even though it may now have to turn in opposite directions at the choice points. The machine does not learn a sequence of responses to a chain of appropriate stimuli. The movements that it makes are of little consequence both in its learning and its performance are always highly variable. It can be "taught" though the trolley be motionless and the machine be "paralysed" and make no motor response. The trolley will make an errorless run even when it is partially crippled.

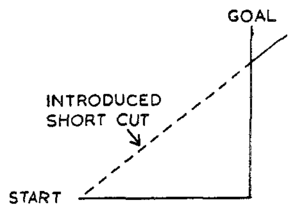
FIGURE 2



The machine transfers its training from A to B and vice versa, but not from A to C.

The flexibility and variability of its performance may be illustrated by its ability to take advantage of short cuts.

FIGURE 3



The machine will take a short cut if it is made available.

After learning a maze, the machine will take a short cut, if one is introduced leading to a point nearer the goal. Similarly, it will take short cuts introduced when it is finding its way from the entrance of one maze to the goal in a second.

The machine can also be trained in operant conditioning situations, multiple choice discriminations and related problems.

The system

The behaviour described above is the behaviour of a certain type of system. The properties described are not those of relays but of arrangements of relays. Further, we can make the same arrangement, manifesting the same behaviour, out of other components—thermionic valves, transistors or wheels. Perhaps a similar arrangement is to be found in the mammalian central nervous system. After all, the mammal manifests similar behaviour.

The abstract system itself which is richer is described elsewhere (Deutsch, 1953). Here are described the operations which the machine performs and its particular embodiment as represented by this machine.

On the learning trial (before the goal is found) the system arranges the receptors in an order inverse to that in which they were stimulated. The receptor which was set off first will be last in the series, and the last one next to the first. The first position is always occupied by the goal-signalling receptor. There will therefore be a record of the order in which certain aspects of the environment occur in relation to the goal.

This order is preserved by making a pulse from a receptor travel to the trolley through a contact on relay with what might be called a particular number. The relay with the lowest number has the goal-signalling receptor already attached to it, and when it is switched on and closed by the operator, all the relays with higher numbers are closed, enabling any receptor attached to any of them to control the trolley, whichever it is that may be stimulated.

But when a pulse passes through any relay, all those relays which have a higher number will open and stay open, so that the receptors attached to them will not be able to influence the movements of the trolley. This will be called the hierarchical arrangement. It ensures that the trolley will always steer towards that "landmark" which it "saw" nearest (in time) to the goal.

When there are two series of receptors made, each registering the order of "cues" leading to the two goals, if there is a receptor common to both series, the system will exploit this information. When one of the goal-signal receptors is closed by the operator, it will be recalled that all the relays with higher numbers will also be switched on. Now one of the relays with a higher number has a receptor common to both series attached to it; through this common receptor will now flow excitation closing all the relays in the other series with a higher number. This gives the system "insight."

The machine

The system is embodied in the following way. First is the "thinking" part, composed of six uniselectors and twenty-three relays. The second is the trolley which moves through the maze, and the third consists of the photocell-receptors. The trolley has a light mounted on it, which is thrown forward at a wide angle, and which touches off the photocells mounted on each sector of the maze. (This arrangement was adopted as a practically easier equivalent of mounting receptors on the trolley and placing the signals in the maze.) The trolley has two responses: it either goes forward or turns round on its axis. When it has been set to learn its way to a goal, it goes forward (except when it bumps into the walls of the maze). When it has been set to find its way after it has learnt, it will continue to travel forward as long as a particular receptor which the machine has selected is being stimulated. When this stimulation ceases, the machine will turn until the stimulation of this receptor occurs again. It will thus guide itself towards the selected receptor. This is the way in which the trolley is controlled.

The way in which the machine stores the order in which the receptors were stimulated on the learning trial is now described. (See Figure 4.)

Each receptor is connected to its uniselector before it has been stimulated, in such a way that its stimulation will move the wipers of its own uniselector to the first position and the wipers of any other uniselector whose receptor has already been stimulated to the next position. Once it has been stimulated and the wipers shifted to the first position, the stimulation from its own receptor will not affect it; nor will it affect any other uniselector. It will now only be shifted by a receptor which is being stimulated for the first time.

This will be made clear if we study Figure 4. The uniselector U1, which is moved when receptor 1 is stimulated, has two principal states.

1. The state before receptor 1 has been stimulated. Here only the closing of relay R1, caused by the stimulation of receptor 1, will move the wipers of U1 from position O. Any pulse from R2, closed by the stimulation of receptor 2, will not affect U1 because the circuit which effects this is broken at U1, row b.

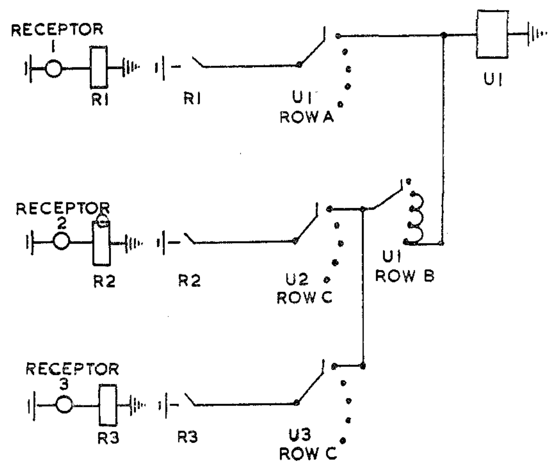
2. The state after receptor 1 has been stimulated. Here the closing of R1 will not further affect U1, because the wipers have now been shifted to position 1. And thus the circuit which shifts U1 when R1 closes will have been broken.

On the other hand the circuit which connects U1 with R2 and R3 is now closed by U1, row b. U1 will therefore be stepped on when R2 or R3 close. But U1 will only be affected if R2 (or R3) close for the first time because the circuit leading through U2 row c (or U3, row c) will be broken as soon as the wipers have been moved from position O.

When considering receptor n, substitute n for 1 in the above description and vice versa.

Now, if there are three receptors stimulated in turn, it follows that the uniselector attached to the first one to be stimulated will be on the third position, the next on the second position and the last on the first position.

FIGURE 4



The circuit used for attaching receptor 1 in its place during learning.
For receptor 2, exactly the same circuit is used, but 2 should be read in place of 1, and vice versa.

The receptors are also connected through wipers to the positions, each of which is separately attached to the hierarchical arrangement. Thus the nearer in time to the goal a receptor was touched off, the higher in the hierarchy is it connected. Once the goal the machine was set is found, the connection becomes permanent. As on the learning run the trolley is made to "explore" each alley or sector in turn before it reaches the goal, the receptors are connected to the hierarchical arrangement in accordance with their proximity to the goal-receptor.

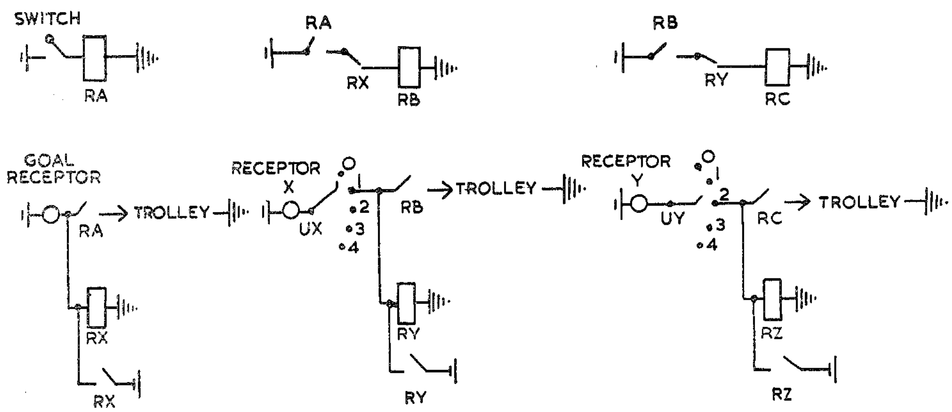
The order thus preserved is utilised in the following manner. (See Figure 5).

The receptors are connected by uniselectors to a hierarchical arrangement of relays. By this is meant that the relays are connected in a series in which the energizing of a preceding (supraordinate) relay causes the closing of its successor (subordinate), and the switching off a predecessor leads to the opening of the relay whose closing it previously caused.

The receptor whose stimulation functions as goal (two in the present model) is "innately" connected to the "make" contacts of the first relay in this series (RA) (again two in the present model) (see Figure 5). The rest of the receptors (x, y) are also connected to the "make" contacts of relays but each is connected to its respective relay in the hierarchy through the activity of its uniselector (Ux, Uy) during the "training" trial. Each receptor is connected at the same time to close another relay (RX, RY, RZ) which breaks the circuit of the relay subordinate to the one to which the receptor is also connected by the uniselector. When the hierarchy is switched on ("when there is a drive acting on the organism") the stimulation of any receptor connected to the hierarchy will cause the trolley to go forward while this stimulation continues, because it is connected to the trolley through the "make" contact on its relay in the hierarchy and secondly, will immediately lead to the opening, for the rest of the trial, of all the relays subordinate to that to which it is connected.

During the "training" trial the hierarchy is not switched on. Instead the circuit which allows the receptors to drive the uniselectors is closed, to be opened when the finding of the goal receptor is signalled.

FIGURE 5



←——supraordinate subordinate——→

The so-called hierarchical arrangement which selects the "cue" which the trolley is to approach. The make contact of relay RB is connected to the first position of every uniselector, (the previous position is designated O, because it leaves a receptor unconnected). RC is connected to the second, and so on.

On being set in the entrance of the maze on the test trial the machine is set to find the goal. The hierarchical arrangement of relays is now switched on and some receptors again pick up signals.

As has been explained, the receptors when they are stimulated send a pulse to the trolley through that portion of the hierarchy to which they are attached, but only when this portion is switched on at the same time. A portion is switched off as soon as another portion supraordinate to it has passed a pulse from the receptor, attached to it, to the trolley. Hence the trolley will always steer towards the receptor nearest to the goal and bring itself by this means within the range of stimulation of others even nearer until it reaches the goal receptor.

When the trolley has learnt two mazes with a common receptor and two separate goals the one receptor is attached to both hierarchies perhaps with a different position in each. When either goal is then selected, the switching on of the hierarchy subordinate to that goal will be transmitted through the common receptor to portions of the other hierarchy. Only those portions, subordinate to that to which this common receptor is connected, will be switched on. Hence the trolley will find the shortest way to the goal selected in whichever entrance it is set.

The system consists of six uniselectors and twenty-three relays. The uniselectors have six wipers each, and are ordinary P.O. equipment. Only three positions are employed on each. Smaller ones would thus be more suitable, were they obtainable. The relays are similarly large P.O. relays with four "make" and one "break" contact. These also are often not all used, but the writer and constructor was led to use them because they were cheap and readily available and because he believes that he would have become intolerably confused had he used more than one type.

The system is such that it could be expanded without a loss in efficiency. For instance, even the time taken to calculate a choice or reach a decision (when there is no conflict) does not vary with the complexity of the operation (and the size of the system); it takes the machine no longer to select the path to a goal whether it has to combine information acquired in separate situations or not. This, with the number of complex properties which this relatively simple system has in common with a mammalian organism is encouraging from the point of view of theoretical psychology.

Reference

Deutsch, J. A. (1953). A new type of behaviour theory. *Brit. J. Psychol.*, **44**, 304–317.