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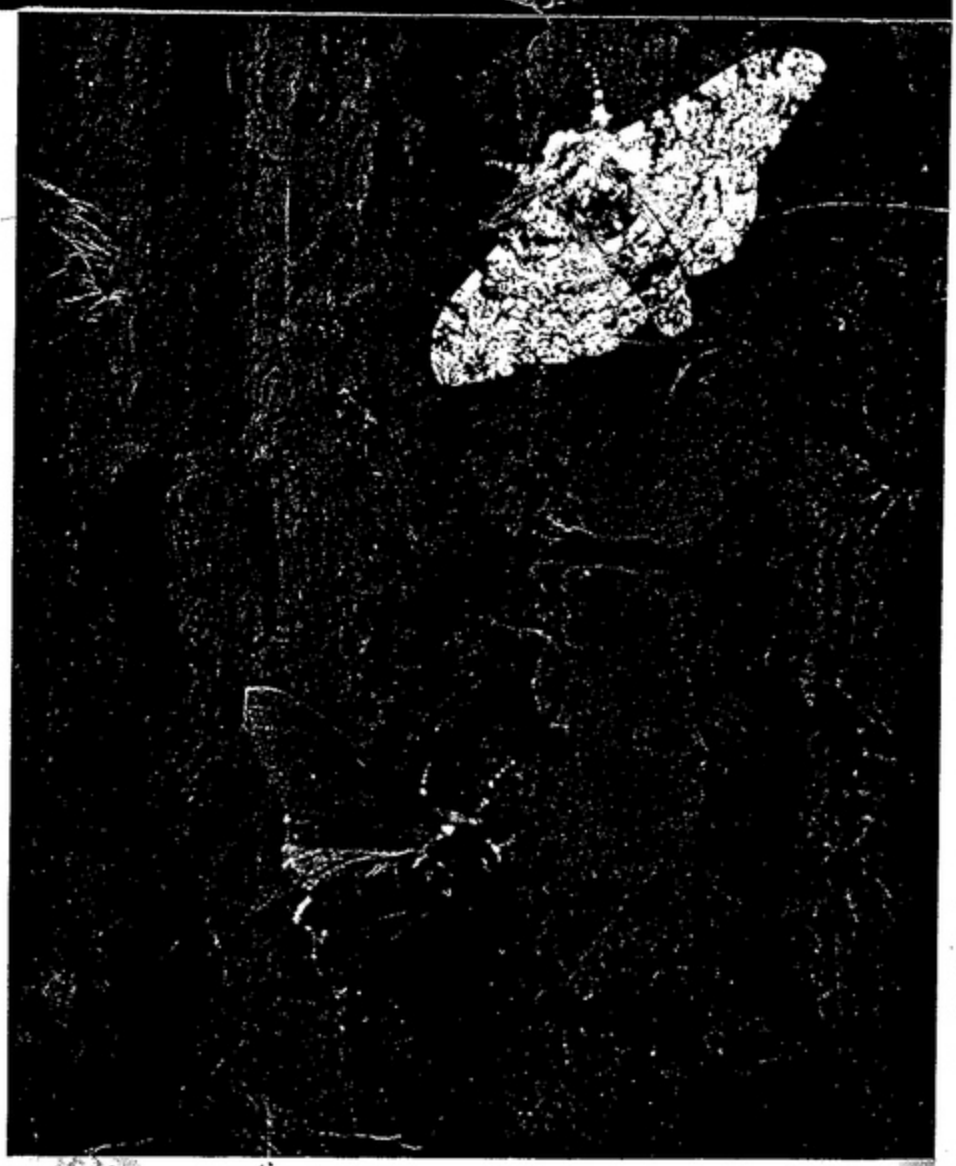

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FIG. 1 (*below*). A picture of the trolley showing the lamp which stimulates the photocells. On the trolley are bumpers which when touched cause one of the motors to reverse, thus causing the trolley to turn away from the obstacle. The "brain" part of the machine sends a pulse to the trolley, when the trolley is required to turn.

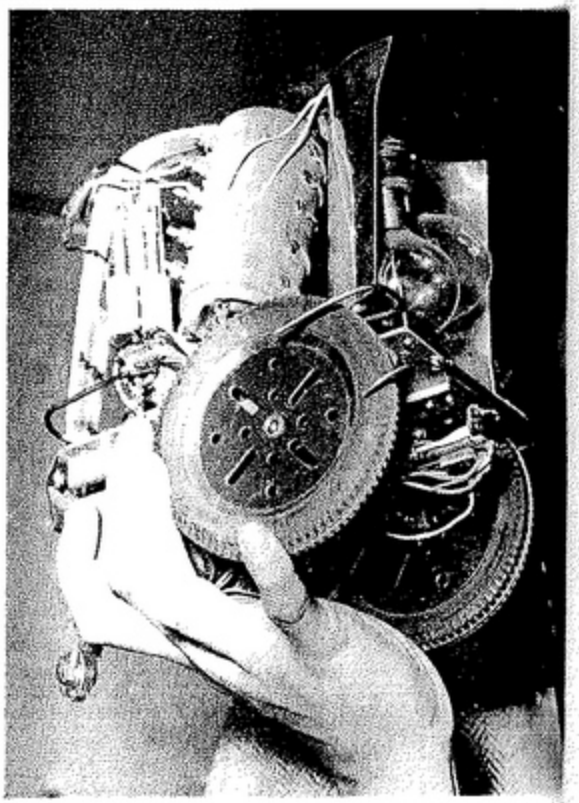

FIG. 2 (*above*). The "brain" part of the machine. Here the order of stimulation is recorded. Decisions are made in it on the course of action using the evidence of what happened on previous occasions and the information about the present situation. On the input side there are the photocells, with functions analogous to the sense organs; on the output side there is an on-off relay which controls the signal sent to the trolley. There are also two switches manually set before each trial, which determine the "motivation" of the machine and thus which goal it will attempt to reach. This part of the machine is entirely electro-mechanical. It is composed of relays and uniselectors. The robustness, simplicity and reliability of these are of great advantage especially as high speeds of operation are not required in this type of system. The uniselectors are furthermore ideal for the storage of serial orders, the principle on which the "memory" of this machine depends. The disadvantage of this type of embodiment lies of course in its large weight and size and its relatively high power consumption. This means that it is hardly feasible to combine the moving and "thinking" parts of the machine as is done in a biological organism. However this is not a limitation of principle. With miniature components this unification could no doubt be achieved.

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THE INSIGHTFUL LEARNING MACHINE

J. A. DEUTSCH, M.A.

Institute of Experimental Psychology, University of Oxford

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Analogies have often been drawn between the operation of the brain and the great electronic calculating machines. Such comparisons, though interesting, have, in the view of many, lacked complete plausibility. There was a feeling that these machines lacked an element of adaptability and originality with which human organisms were credited. Though these misgivings have been vaguely expressed and need more careful definition, they contain an element of importance. The ability to solve a new problem by utilising information acquired on different occasions and under diverse circumstances has been found even in such animals as the rat. The elasticity of this animal's behaviour can be demonstrated, for instance, by its readiness to take short cuts as soon as they are presented in a maze which it has learnt. Such ability to solve fresh problems without further learning has led the psychologist to speak of the animal's previous learning as *insightful*.*

The machine to be described manifests many of the properties which would be called insightful if observed in an animal. It is shown with this machine that these abilities are all properties or facets of a relatively simple system.

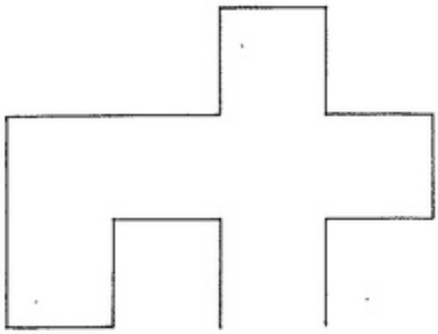
THREE MAIN COMPONENTS

The machine consists of three main parts. The first is a small square trolley. This has a bulb mounted on it in such a way that a wide cone of light is projected forward. There are also bumpers fixed on the front edge and the two sides. According to which of these bumpers is touched, one of the two motors driving the two wheels propelling the trolley is thrown into reverse. This causes the trolley to steer away from any obstacle with which it has come into contact as it moves around. One of the motors is similarly reversed when the trolley receives an external pulse; while this pulse lasts the trolley will turn, and when it stops both the motors turn in the same direction again and the trolley goes forward.

The second part of the machine consists of a maze with photocells mounted at intervals on the walls. It would have been possible though somewhat inconvenient to fix the photocells on the trolley and put suitable signal-lights in the maze instead. To put the sense organs in the environment instead of on the animal does at first sight appear to destroy the analogy between the rat and the machine. However, in spite of its removal from the trolley the sense-organ still performs the same function; it conveys to the machine the same information about its whereabouts as if it was mounted on the moving trolley. It does this by means of a separate "brain".

The third part of the machine consists of relays and uniselectors and fulfils the functions of the brain. It is here that the information arrives and is sorted, and from here that orders are sent to the moving parts. It consists of six uniselectors and twenty-three relays. It is therefore quite bulky. It could of course be made much smaller if we used components like transistors, and smaller still if it was possible to substitute nerve-cells. We could, with a great deal of technical virtuosity, then combine the trolley, the "sense-organs" and the "brain" in one whole in the same way as they are combined in an animal.

Nevertheless when we watch the trolley in the maze we soon forget that its sense-organs are not on the trolley but in the maze. In fact even those who know the inverted arrangement intimately cannot help employing conventional terminology and talking of the trolley "spotting a landmark". Hence to recreate the illusion for the reader we shall use the phraseology which would be appropriate to a real animal. The environment in which the machine shows its paces is a modified rat maze, a sequence of alleys only one of which leads to the "goal". The arrangement is shown below.



On its first run the trolley is made to enter each alley in turn. This is done by blocking off the various sections in turn. This is a procedure often used with rats, and in this case it is an expedient which saves time in demonstration and "storage capacity" in the machine. When the machine has thus traversed the whole maze and reached the goal which is a photocell connected to a particular section of the central relay system, it can be set again at the entrance of the maze with all the blocks removed and set the task of finding the goal again. This is simply done by turning a switch. Now here it will be said that this is different from an animal.

*The word *insightful* refers to a type of behaviour which cannot be explained by assuming that an animal when it is learning simply associates or connects a given signal or stimulus with a certain movement or response. However, all the machines made with the express purpose of imitating learning behaviour are based on this principle. Evidence accumulated by experimental psychologists makes it dubious whether this is the principle underlying even the simpler forms of learning.

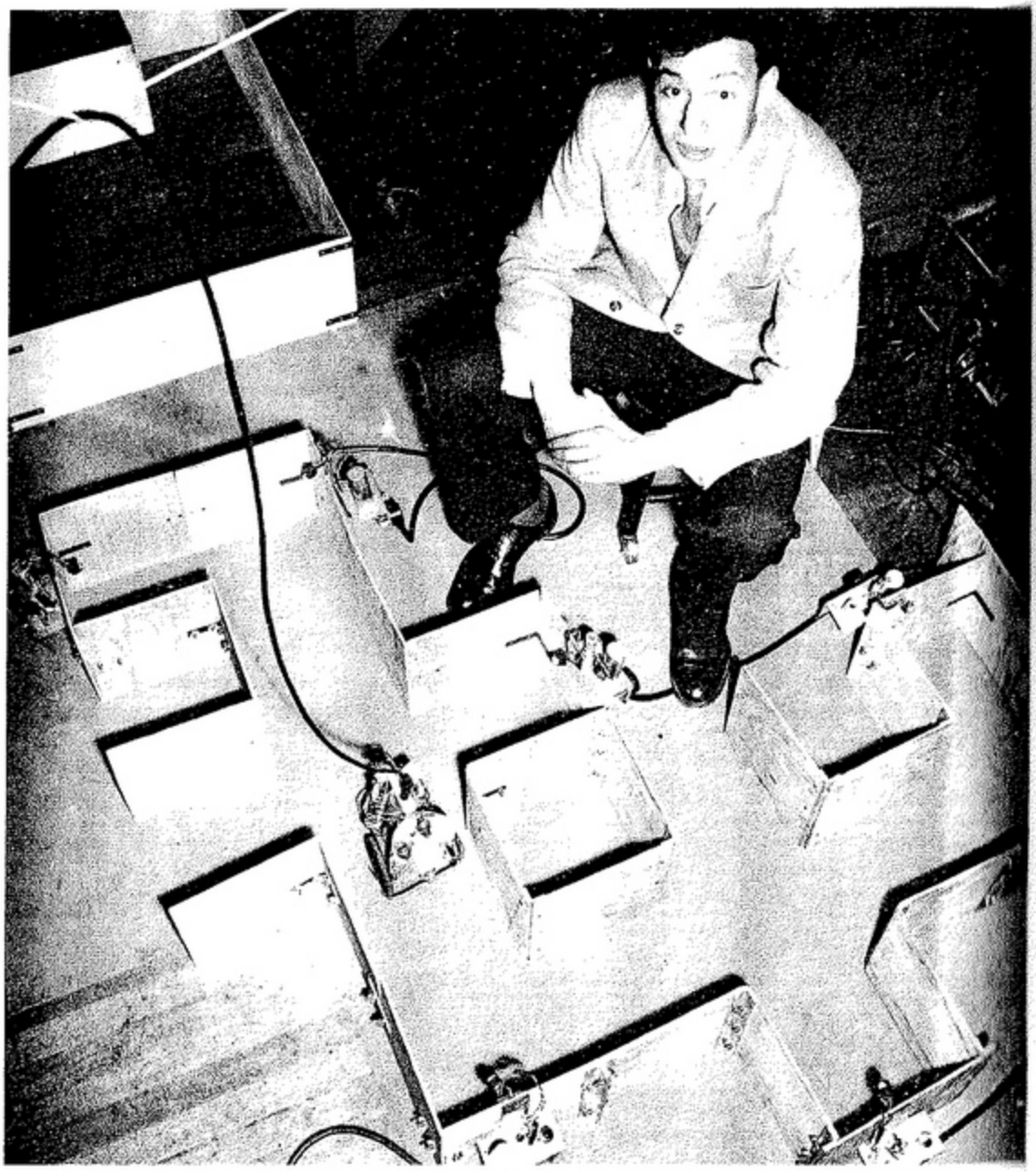


FIG. 3. View of the rat maze or labyrinth in which the trolley runs. On the walls of this labyrinth can be seen the photocells which the lamp on the trolley stimulates as it moves through the maze. Here again it would be possible to have the sense organs on the moving trolley. However, the present arrangement is technically more convenient for three reasons. It is unnecessary to devise a special coding for each signal in order to keep it distinct. The difficulties of conveying the separately coded signals from the moving trolley to the stationary "brain" are avoided. The trolley can be made less bulky. In spite of this somewhat unorthodox reversal (of stimuli on the organism and sense-organs on the environment) the total effect is the same.

The maze portrayed is like those used in work with rats. The machine is made to learn it in two separate trials. Each half of the maze has a different goal in it for the machine. The goal is achieved when a certain photocell is stimulated. After the machine has learnt the two halves separately, it can combine these two experiences and cross from one half of the goal to the other (if "motivated" to do so) without error. If clearly "visible" short-cuts are put in, the machine will take them without any further trial and error.

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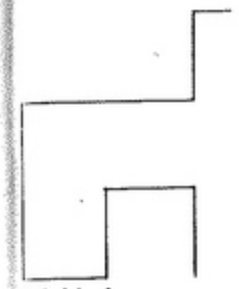

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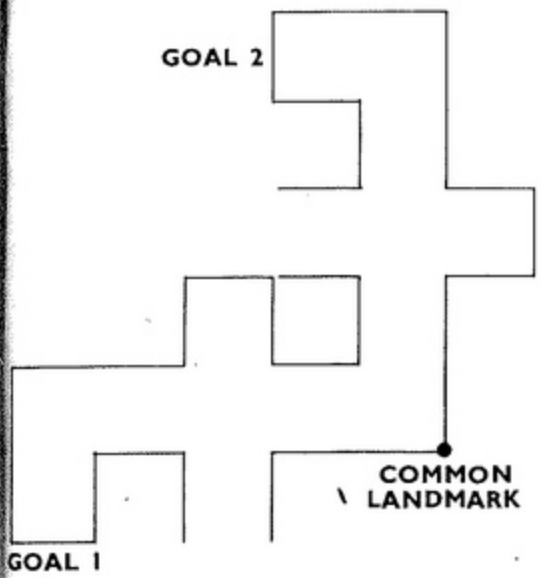
An animal is spontaneous. It sets its own goals without external manipulation. This is true. When we require a rat to go to the goal box we do not press a switch. We have unfortunately to resort to food deprivation instead, which though practically less convenient can normally be identified with turning a switch. The goal having been set the trolley will now choose the correct way to the goal avoiding any blind alleys.

If in the meantime we have inserted a short-cut in the maze through which the trolley can "see" a feature nearer the goal it will take this short-cut immediately without any further learning.

The machine will repeat its performance time after time without entering a blind alley though no two runs as defined by the movements of the trolley are alike. The trolley can be picked up in the middle of a trial and turned right round without "getting confused". Similarly it can learn to run the maze correctly even though on the learning trial it does not move at all under its own steam and is just taken round by the demonstrator and "shown" the maze. A machine embodying Pavlov's conditioning principles would not have most of these abilities.

After we have put the machine through its paces on one maze it is now possible to make it learn a second one containing another goal, which it can "remember" concomitantly with the first. If the second one has a feature or landmark in common with the first as indicated in the following diagram we can set it an interesting problem.



If we place it at the entrance of the first maze from which it has learnt to find its way to Goal 1 on a previous occasion, we can set it to go to Goal 2 in the other maze. It has never in fact been from Maze 1 to Maze 2 before as the way was blocked. Nevertheless it turns into what was previously a blind alley when it comes to the first choice point and goes towards the common landmark. After reaching this it runs towards Goal 2 without entering a blind alley. The machine may thus be said to synthesise "knowledge" gained on separate occasions to use it in solving a new problem. This type of ability is displayed by the rat in the latent learning situation and N. R. F. Maier's experiments on reasoning.

This kind of behaviour might perhaps be more pardonably called goal-seeking or purposive than that displayed by machines exhibiting simple tropism or merely incorporating a homeostatic device. The mechanism of tropism was suggested by Loeb at the turn of the century and he is reputed to have built a cigar-box with a "nose" which would follow a light. The reader may be familiar with more modern imitations. The present machine uses a simplified version of the Loeb machine as a small part of its design. When the light on the trolley is switched on the machine goes forward if the light from it is falling on a selected photocell and begins to turn when this photocell is no longer illuminated.

On the learning trial only the goal photocell is selected and before it is picked up the machine will go forward except when it turns because of an obstacle. However, as it traverses the maze the other photocells are triggered off. They are triggered off in a certain order. Some will be stimulated nearer in order to the "goal" cell, others farther away. This order is preserved by means of uniselectors which connect each photocell up to a particular position on a set of relays. A record is thus kept of the order in which the photocells were stimulated.

SHORT CUTS TO THE GOAL

When the machine is required to find the goal again, the set of relays to which the photocells were connected in order during the learning trial transmits impulses from the photocells to the trolley. But this set of relays is so arranged that if a photocell which was fixed nearer in order to the "goal" photocell, has been set off by the light, the ones farther away are temporarily disconnected. They cannot pass any further message to the trolley which will thus always approach the photocell nearest to the goal. Hence the machine avoids blind alleys and takes short cuts.

Where a common landmark occurs in both mazes a photocell is attached to two different orders or sequences representing the two mazes. When one goal is then selected, the order of photocells leading to it is also indirectly brought into action. The excitation which causes this also travels through the receptor common to both sequences and activates that part of the order which represents the landmarks leading up to that which is common. Thus the correct sequence of landmarks to be approached is already selected in whichever entrance of the maze the trolley is set.