

AN EXPERIMENTAL STUDY OF COUNTING BEHAVIOUR
IN THE WHITE RAT

by

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This statement is to certify that the experiments
described in this thesis were my original work.

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PREFACE

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| | Guidance in a two-turn task in a temporal circular maze.
<u>J. comp. physiol. Psychol.</u> , 1967, <u>64</u> , 505-7. |

- Chen, C.S. Training schedule in a two-turn task in
a temporal circular maze.
Psychon. Sci., 1967, 9, 273-4.
- A study of the alcohol-tolerance effect
and an introduction of a new behavioural
technique.
Psychopharmacologia, in press.

The following abbreviations have been used in this
thesis.

E	Experimenter
Mdn	Median
P	Probability value
S	Subject

ABSTRACT

An enclosed temporal circular maze, which consisted of a circular runway and a radial stem, was developed for the study of 'counting' ability in the white rat. In this maze situation, the white rat was required, after emerging from the radial stem, to circle the circular runway a specific number of times before re-entering the stem for food reward. The findings may be summarized as follows.

(1) The white rat is able to learn tasks requiring two to seven turns to obtain food reward in this maze situation.

(2) Results on control tests suggest that exteroceptive cues, cues of distance, cumulative sensory feedback of running activities, and time are not essential for the successful performance.

From these results it is inferred that the ability of the white rat to learn these tasks, which requires retention of the number of events (e.g., number of turns made) following each other in temporal sequence, may indicate the rudiments of a counting ability.

(3) It is found that in training the white rat to learn a two-turn task, an ordinary trial and error training procedure is very ineffective. A certain amount of guidance (i.e., forcing S to make the required response) is necessary. This result suggests that the maze may provide a useful tool for investigating the effects of guidance on learning.

(4) The effectiveness of various training schedules (a certain combination of guided and free trials) was studied. The results suggest that (i) within certain limits the effectiveness of guidance is in direct proportion to the number of guided trials given, and (ii) the effectiveness of training schedules is the result of the interaction of guided and free trials.

(5) The present maze situation has potential for studying the effects of drugs on cognitive or symbolic aspect of behaviour. Specifically, the effect of alcohol on the white rat's performance of the two-turn task was studied. The effect of alcohol was found to be detrimental in terms of response rate, the number of correct trials achieved, and the number of errors made. Some aspects of alcohol-tolerance effect were studied. The result shows that Ss that had the opportunities of running the maze while under the influence of alcohol perform much better than Ss that had merely been accustomed to the same amount of alcohol but trained in a sober state.

In conclusion it is suggested that objective studies of the behaviour which is featured in this newly developed maze situation can make significant contributions to some neglected area of animal behaviour.

CHAPTER I

INTRODUCTION

Although it may be true that comparative psychologists have concentrated unduly on rats (Beach, 1950; Bitterman, 1960, 1965), there are some aspects of rats' behaviour, e.g., 'counting' ability, about which little is known. Previous investigations of this and related abilities in rats showed that the achievements of rats were surprisingly poorer than those of birds, which have been extensively studied by Koehler and his co-workers (see Chapter II). It is hard to imagine that the rat would be less able than the bird, which is supposed to be lower in the phyletic scale. One probable reason for these results seems to be the inappropriate techniques used in the previous studies.

Besides the compelling curiosity to devise adequate methods for studying this interesting problem in the rat, there is another important underlying motive which led this writer to the present study. If we are going to learn more about animal learning, and to obtain more understanding on certain aspects of human behaviour through studies of animal behaviour, then much effort should be made to study complex processes; and one of the most important needs is to develop better techniques for these studies. The following sentence is worth quoting:

Furthermore, we are firmly convinced that the analysis of simple behavior gives relatively

little information about the nature of complex behavior, whereas the successful analysis of complex behavior may give vast insight into the nature of simple behavior.
(Harlow, 1959, p.494)

Since the author regards the study of the 'counting' ability in the white rat as a means for further research rather than as an ultimate end, exploration of the possibilities of the method developed in the present study was emphasized at the expense of detailed experimentation on each individual problem. The experiments in this thesis, which can be grouped under three main topics, show that the method has great potential in the field of comparative studies, in studies of guidance in learning, and in studies of the effects of drugs on animal behaviour.

The first topic dealt with in this study is the limit of the white rat's capacity in an enclosed temporal circular maze, and the nature of maze behaviour. The experiments under the second topic were mainly studies of the effectiveness of various training procedures on learning of an elementary task (a two-turn task) in this maze situation. Finally, possible application of this maze in studies of drug effects on animal behaviour is discussed. Taken as a whole, they show that comparative psychologists have tended to underestimate what the rat can learn, and that the method developed in this study is worth further development.

CHAPTER II

NUMBER CONCEPT IN ANIMALS

Since some excellent reviews on the 'number conception in animals' are available in the literature (Honigmann, 1942; Salman, 1943; Wesley, 1961), it would seem redundant for this writer to do the same. The purpose of this chapter is merely to provide a brief summary of the main methods related to the studies of the so called 'number conception' in animals.

MULTIPLE-CHOICE METHOD

The main principle of this method is that the animal is required to select one object out of many, which has a certain relationship with the others. The object to be selected is not necessary identical from trial to trial. As for example, in Yerkes' multiple-choice test situation where the correct box varies from trial to trial, but always maintains a definite relation to the others, such as 'the middle one' or 'the second from the right' etc.

Kinnaman (1902) presented two macacus rhesus monkeys 21 glasses of uniform shape on a board and trained them at first to obtain food from 'glass no. 4 from the right end'. Later he trained them to find food in glasses nos 2, 5, 1, or 6 out of a total of 11 glasses. The monkeys were found to be able to learn the tasks. However, Honigmann pointed out that there were two secondary cues

that might be responsible for the successful results, namely, constant distance of the correct glasses from the right end of the row of glasses, and marks on the board, on which the glasses were apparently placed on the same spot. This same method was employed by Porter (1904) with English sparrows, which were required to select glasses nos 1, 2, 3, 4, or 5 out of a maximum of 6 identical glasses. Again, as in Kinnaman's study, the cues due to distance and marks on the board were not excluded.

The multiple-choice method was further refined by Yerkes (1915) for the study of abstraction in animals. The apparatus consists of a series of identical compartments or boxes. During the course of training, however, only a certain number of these boxes were accessible (i.e., opened) to the animal, and it was required to find one that had a definite relation to the others. The number and position of the open boxes varied from trial to trial, and consequently the correct box varied as well. For example, for the second from the right problem, when boxes 2, 3, and 4 are open, the correct one is box 3, and on the next trial boxes 7, 8, 9, and 10 may open, and the correct one is now box 9. The problems used were: (i) the first box on the animals' left, (ii) the second box from the right end, (iii) alternately the right and the left end box, and (iv) the middle box. It is clear that the first and the third problems actually have little to do with the topic in question. This method has been applied to birds (Coburn and Yerkes, 1915; Sadovinkova, 1923), rats (Burtt, 1916), pigs (Yerkes and Coburn, 1915), monkeys

and apes (Yerkes, 1916), and chimpanzees (Yerkes, 1934; Spence, 1939). Coburn and Yerkes found that the crow was able to master problems 1 and 3, but not 2; Sadovinkova found that her finches were able to select the middle-box out of a setting of from seven to nine. However, according to Honigmann, she was without doubt being outwitted by her birds, as the correct door was a swing one and the wrong doors were blocked by means of pin let down from above. The birds might have used this as cue to solve the problem. The pig was able to master problems 1, 2, and 3 but failed problem 4 when seven or nine boxes were used. The monkey was able to deal with all the four problems. However, it is interesting that Yerkes' four chimpanzees failed to master problems 2, 3, and 4, and mastered only the problem of no. 1 type. Spence used a modified apparatus (manipulatory type) and trained 17 chimpanzees on five problems. He found that 15 Ss learned the middle box of five, and all the Ss were able to learn the second box from the left-end box of six, the right-end box of seven and the left-end box of seven.

In all studies, only sets of adjacent boxes were presented, e.g., boxes 3, 4, and 5, or boxes 6, 7, 8, and 9, etc., thus the distance between the correct and the extreme end box of each set might provide the secondary cue for the correct solution of the second from the left (or right) problem. In view of the limited success of the animals studied, the value of this method for the study of 'number conception' in the animal is certainly very small.

THE ALTERNATION METHOD

The second method related to the study of 'number conception' in animals was to test the animals' ability to perform actions either in single or multiple alternation.

Katz and Révész (1909) working with the domestic fowl, used a row of grains of corn, of which every second one was glued to cardboard. The Ss soon learned to eat every loose grain without pecking the fixed ones. One hen even learned to peck every third one and leave the other untouched, but it failed in learning to peck every fourth grain. In a later research (Révész, 1922), the distance between the grains was doubled or halved after completion of the training without disturbing the alternation habits. As Honigmann pointed out in his review (1942), these Ss might just learn to distinguish between fixed and loose grains, as no control test, in which all the grains were loose, was carried out. Honigmann (1942a) succeeded in demonstrating what appears to be a true single alternation habit in the hen in which other extraneous cues were excluded. According to his opinion, 'even a simple alternation, performed in a "multiple way" without any secondary cues (discrimination of fixed and loose grains) and independent of the distances between them, can be considered as a preliminary stage to counting' (p.324).

The second method in this category is the well known double-alternation temporal maze problem, developed by Hunter (1920) and used mainly with mammals. The ground

plan of the maze used by Hunter in an earlier study is shown in the following diagram.

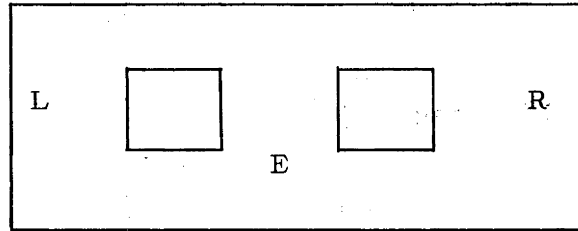


FIGURE 1. Diagram of Hunter's double-alternation temporal maze; E, entrance; R, right; L, left; (modified from Hunter, 1920, p.6).

In this maze situation, the animal is required to turn twice to the right and twice to the left (or vice versa). Thus in making these turns the animal is not aided by any differential sensory cues at all, for it has to make each turn at the same choice point. As Hunter pointed out:

It is impossible for one and the same stimulus to cause first one response and then another unless it is supplemented by some other factor either inside or outside the organism....The experimental situation rules out the possibility of a supplement from outside the subject's body. If the subject masters the problem, it can be only because some supplement within the animal's body is presented.... (1928, p.377).

The supplementary processes proposed by Hunter are either (i) the cumulative effect of the responses already made, or (ii) a symbolic process involving the same function as

counting behaviour in man, but on a more primitive level. Hunter himself favoured the second mechanism.

Gellermann (1931), working with monkeys, developed an alternative procedure, in which S is required to choose a box to open (manipulatory type) rather than to run the maze (locomotor response). The procedure is further adopted in the Wisconsin General Test Apparatus (e.g., Stewart and Warren, 1957).

The double-alternation technique has been applied to rats (see below), rabbits (Livesey, 1964 and 1965), racoons (Hunter, 1928; Johnson, 1961), cats (Karn, 1938; Karn and Patton, 1939; Stewart and Warren, 1957; Yamaguchi and Warren, 1961; Livesey, 1965), dogs (Karn and Malamud, 1939), and monkeys (Gellermann, 1931 and 1931a; Warren and Sinha, 1959). All the species studied were able to learn to some degree the sequence of LLRR (or RRLL) response, but none was able to extend 'the principle of alternation' beyond the sequence which it was trained on, except the monkey which was able to extend to as many as 16 RRLL sequences (Gellermann, 1931).

In all the experiments using the locomotor response, only one (i.e., Karn and Patton, 1939) bothered to control cues of distance. They were able to transfer their cats to temporal mazes of different sizes after Ss had acquired the double-alternation behaviour in a standard training maze, which suggested that the cumulative effect of the response was not the operative cue for the successful performance. In those experiments involving manipulation (most of which were

carried out in the Wisconsin General Test Apparatus), there seems to be no active control of the possible involvement of secondary cue from the odour of reward. For example, in Stewart and Warren's study (1957), fresh kidney was used as the reward; therefore there was the possibility that their cats might be guided solely by the odour of the reward.

THE DISCRIMINATION METHOD

There are two main methods under this category, namely, simultaneous presentation and successive presentation of numbers of stimuli to be discriminated. In the former method, a bird may be required to select one of two groups of edible units (grains of corn, fruit, pieces of meat, etc.), or learn to choose one of five boxes which had the same number of spots on its lid as there were on a 'key' card lying on the ground in front of the boxes to be chosen. A monkey may be required to select one of two cards presented side by side on the basis of number only, irrespective of extraneous cues, such as size or stimulus configuration. In the second method the stimuli or events are presented successively in temporal sequence, and the animal is required to estimate or to remember the number of items in succession, which is independent of rhythm or any other extraneous cues that might be helpful. Thus a bird may be required to eat only 'x' grains out of many offered, to eat only 'x' peas that were rolled into a cup one after the other at irregular interval, or to open lids of boxes standing in a row until 'x' baits that were randomly distributed among the boxes are obtained. For

a monkey, the task may be to open the trainer's clenched hand twice to obtain food or to reach for food in response to the number of sounds that indicate the position of the reward.

The discrimination method has been employed by Hassmann (1952) on squirrels, and by Woodrow (1929), Kuroda (1931), Gallis (1932), Kühn (1953) and Hicks (1956) on monkeys. Hassmann reported that her squirrels were able to discriminate seven irregular dots from three, four, five, and six dots presented simultaneously; on the successive task one S was able to reach the six level. The results of the first three studies on monkeys were less satisfactory, both for the poor achievement, and most importantly for lack of adequate control of extraneous factors (in the case of Gallis and Kuroda's). Kühn reported that his monkey was able to discriminate seven from eight dots which were independent of size and spatial arrangement, and presented simultaneously. Hicks, using a visual discrimination technique, was able to train his monkeys to form a so called 'three-ness' concept. A special feature of Hicks' study is that he used entirely new stimulus cards on control tests.

Much work has been carried out by Koehler and his co-workers on several species of birds. The work has been nicely summarized by Thorpe (1963), and critically reviewed by Wesley (1961), and thus will not be repeated here. Their work is characterized by the rigorous control of every possible extraneous cue, such as the 'Clever Hans' type error, temporal rhythm, size, figure of the number of units, etc. Some remarkable results were obtained by these research workers. For example, Koehler

(1943), using the 'match the key' method mentioned earlier, trained a raven to open a box that had the same number of dots on its lid as there were on a key card. All possible extraneous cues were randomly changed from experiment to experiment, and the birds still were able to select, from five lids that had two, three, four, five, and six irregular dots on them, the one that matched the key card in number of dots. Lögler (1959) was able to train a grey parrot to eat exactly eight baits that were randomly distributed among a row of 11 food trays. He even demonstrated the bird's ability to combine successive presentation of a number of optical stimuli with a task of 'acting up' to the equal number, e.g., to eat only six or seven baits distributed in a row of food trays after having seen six or seven flashes of light. Even more astonishing is that when the flashes of light were replaced by the tones of a flute, the bird was still able to take only two or three baits in a row of eight trays according to the number of the tones without requiring further training. The same bird was also able to transpose from simultaneous-successive combination to the simultaneous-simultaneous one, i.e., when the bird had learned to act up to two or one after having heard two sounds or a single sound, he was able to open a lid with two dots or one dot on it according to the same acoustic signal without re-learning. According to Thorpe (1963), this result 'does bring the counting achievement of birds a step nearer that of man; though it is still not true counting in the fully human sense' (p.393).

Recently, Ferster and Hammer (1964) trained chimpanzees to recognize numbers and to 'write them out

in binary form'. They taught the animal at first to choose from two binary numbers present side by side, the one that corresponded to the number of objects shown in the middle of them. The size, shape, arrangement and other physical properties of the objects presented were randomized, and both Ss learned to select the correct binary number ranging from one to seven after 500,000 trials of training. Following that, they were trained to 'write' out in binary form the number of the objects presented. After 170,000 trials of training Ss were able to master the task, again from one to seven. The tremendous number of trials required seems to be due in part to the complexity of the indication response, i.e., the chimpanzees had to learn to discriminate not only the number of the objects presented, but also the binary system.

RELATED STUDIES IN THE RAT

Burt (1916), using Yerkes' multiple-choice test, trained rats to learn two problems: (i) to choose the door on the right end of a series of doors, and (ii) to choose the second from the left of a series of doors. As mentioned earlier, the number and position of the series of doors accessible to Ss varied from trial to trial; consequently the correct door also changed from trial to trial except that it was always the right end one or the second one from the left. Burt found that the rat was able to solve the first problem, which as Burt pointed out, could be explained in terms of visual, tactual, and kinesthetic cues. None of his Ss mastered the second problem even after very extensive training.

The failure might be due to factors such as the ambiguity of the stimulus situation (it is doubtful that each set of doors was clearly presented to Ss), and delay of reinforcement after a correct choice had been made (Ss had to traverse a distance for food reward).

Atkins and Dashiell (1921), using a four-box multiple-choice apparatus, trained white rats to go to the first, second, or third of the three boxes that were illuminated in irregular temporal order. For example, for the first box problem, boxes nos 4, 2, and 3, might be illuminated in this order, and the correct response would be going to box no.4; on the next trial nos 3, 1, and 4 might be illuminated in this order and the correct one would now be box no.3, etc. This method differed from that of Burr's in that each set of boxes were presented in temporal order rather than being presented spatially and simultaneously; thus some ability to remember the position and the order of the boxes illuminated was required. However, there seem to be at least two improvements in the technique. Firstly, the experiment was carried out in a dark room, and thus each set of boxes was presumably more easily perceived, since the non-illuminated or irrelevant box was kept out of the learning situation. Secondly, the food box was placed immediately behind the correct box, thus the reward would be more prompt than in Burr's case. Irrespective of these advantages, none of their Ss mastered these problems; every S (except one that was discontinued after 160 trials of training) soon developed a right or left position habit, which according to the authors, prevented the solution of these problems.

The double-alternation temporal maze problem was developed by Hunter (1920 and 1929) and applied at first on the white rat with negative results. In a later study (Hunter and Nagge, 1931), when S was at first aided by differential sensory cues which were later gradually eliminated, some rats were able to perform the required LLRR response sequence in a temporal maze. In this experiment four T-shaped discrimination boxes were placed side by side, S was then required to go left in the first and second boxes, and to go right in the third and fourth boxes. After the response sequence LLRR were established in the four boxes, S was then required to run LL in one box and RR in the other, and finally it was required to run all LLRR in the first box which had been converted into a temporal maze. Some Ss learned the double alternation behaviour in this manner, but like other higher organisms mentioned earlier, they could not extend the LLRR series on which they were trained.

One of the practical difficulties of the double-alternation temporal maze technique is the now well-known phenomenon of spontaneous alternation behaviour in the rat (e.g., see Dember and Fowler, 1958), which Hunter himself had realized and concluded that 'it seems safe to affirm that these are innate reactive tendencies of the rat' (1920, p.9). In order to avoid this difficulty, Keller (1937) devised a new type of double alternation problem, in which Ss were required to go down, down, up, up, instead of LLRR. He found that the rats were able to master this problem to a level of at least 85 per cent correct in ten consecutive double

alternation trials. Schlosberg and Katz (1943) trained rats to learn a double-alternation bar-pressing problem, in which they were required either to move a lever two times up and then two times down or to move the lever twice to the right followed by twice to the left. The rats learned the problem. However, since the response sequence occurred in a very short interval without any intervening behaviour, the results are generally regarded as due to the first mechanism proposed by Hunter, namely, 'a cumulative piling up in the nervous system of the retained effect of the responses already made' (1928, p.378); the shift in strokes was conditioned to the cumulative trace of the previous actions.

More recently Livesey (1965) trained eight white rats on a double-alternation problem in the Wisconsin General Test Apparatus (a manipulatory type), in which the position of the reward was twice in the right well followed by twice in the left (or vice versa). Seven out of the eight rats master this double-alternation problem to a criterion of 80 per cent correct responses over 50 consecutive sequence of responses. Unfortunately, it is apparent that no attempt was made to control the possible odour cue by baiting both wells on each trial (pellets of rat food were used as reward). It is generally assumed that the rat, with a very well developed olfactory structure, has good sensitivity to odour.

Ellis (1933) trained eight albino rats in a modified jumping apparatus. In his so called 'counting experiment', Ss which had learned a brightness discrimination in this apparatus beforehand, were

trained at first to jump three times to the left and on the fourth trial to the right, or three times to the right and the fourth time to the left. This training stage was actually a continuation of the brightness discrimination training, in which the positive card was placed three times to the left (or right as the case might be) and shifted to the other side on the fourth trial. However, on the critical test, the condition on the first three was the same as that during training, i.e., the positive and negative cards were presented to guide S's response, and on the fourth trial (so called critical trial), both stimulus cards were made the same (all positive cards). According to the author, there were no extraneous cues to guide Ss which side to jump. The results showed that six out of eight were able to jump to the required side. The author did realize that the results did not permit the conclusion that the rats could count, but he thought that they gave some indication in this direction. It is very probable that Ss were only responding to the change of the stimulus card per se. During the training stage, the stimulus cards were changed on the fourth trial, and on the critical test, making the stimulus cards the same actually changed the stimulus complex and this might account for the positive results. Furthermore on the first three trials, Ss were clearly guided by the positive (or even the negative) stimulus card; there seems to be no need to assume that counting was involved.

Kuroda (1939) trained ten white rats to discriminate number of acoustic stimuli (call bell), in a T-shaped discrimination box. Subject was required to associate

each of a pair of numbers given in the form of sounds of a bell with right or left turn. The result showed that Ss could not discriminate one from two and three acoustic stimuli, but were able to differentiate five from one, two, and three. Two Ss were even able to discriminate between five and four sounds. Since the interval between successive stimuli was kept constant throughout the experiment, it is likely that Ss did not base their successful performance on the number of sounds per se, but rather on the time interval between the first and the last stimuli. This view is indirectly supported by Woodrows' (1929) study on monkeys; when the interval between sounds in the groups of two was made equal to that between the first and the last sounds in the groups of three, the acquired habit of differentiating two and three disappeared.

It was not until the study of Wesley (1959) that rigorous controls of extraneous or secondary cues comparable to those of the work on birds were introduced into the study of 'number concept' in the rat. He employed two methods successfully used by Koehler and his co-workers on the birds, namely, simultaneous and successive discrimination methods. A linear runway-type maze with ten left side alleys with a starting box at one extreme end was developed for the successive method. Subject is required after running out of the start box, to learn to enter the second open alley. The total number of open alleys varies from two to six. For example, on one trial when alleys nos 6 and 10 are opened and the remaining eight are closed, the correct alley is no.10; on the other trial, alley nos 1, 3, 5, 7, 9, and

10 may be opened and the correct one is no.3, etc. Thus the position of the correct alley varies from trial to trial. The distance between the correct alley and the starting box, and the distance between the correct and the first open alley can be varied as well. At this point it is clear that this method is actually a variation of the multiple-choice method. Seven albino rats and seven hooded rats were assigned to seven training conditions (corrective vs noncorrective by aided vs nonaided; three aided conditions being used); the result showed that at least three Ss showed mastery of the problem, but the correct response was not very stable and occurred solely at the end of massed practice. This result was later interpreted by the same author in his review article (1961) as that 'the rats may have responded only to oneness', for the rats may only learn to avoid the first open alley rather than to enter the second open.

A modified Fields' (1953) serial multiple visual discrimination apparatus was used for studying the simultaneous discrimination ability of the rat. Nine hooded rats were used to learn a 'twoness', a 'threeness' problem, or both. Some Ss were at first aided with size, location, figure, and rotation of the units, and others were not aided. Three Ss were able to retain the acquired habits of selecting the stimulus card that contained two units, even though all the stimulus cards presented in each trial were entirely new to them. On the 'threeness' problem, four Ss were able to perform beyond chance level at first, but the acquired habits

could not be retained when the triangularity arrangement of the units was excluded.

It is thus clear from the above review that the number ability in the rat has not been so extensively and properly studied as that of birds. Of the ten related investigations reviewed, only one attempted actively to control the extraneous cues. Furthermore, the limitation of the techniques used in these studies is clearly reflected in the poor achievements of the rat. A further attempt on this interesting problem appears to be desirable.

METHOD USED IN THIS STUDY

At the very beginning of developing adequate techniques for this study, the simultaneous discrimination method was excluded for the following reasons:

- (1) this method required simultaneous presentation of groups of exteroceptive stimuli, which would certainly involve other secondary cues such as brightness, size, intensity, etc., that not only would impede the discovery of the relevant aspect of the stimuli (i.e., number alone) but also would require more effort to control them, and
- (2) the necessary involvement of sensory processes would reduce the value of the method concerned for comparative studies. For example, in visual discrimination problem, the white rat is certainly no match for the bird.

Thus the successive presentation method was adopted and an enclosed temporal circular maze developed. It is hard to recall how this maze was developed, but in the course of attempting this, three guiding criteria for the desired technique were rigidly applied:

- (1) not to require any exteroceptive stimuli, such as successive presentation of number of sounds, flash light, etc.; this is to avoid the same difficulty involved in the simultaneous method,
- (2) not to require any special manipulatory ability, and
- (3) not to require any handling of S during the course of training.

The features of this maze will be described in the next chapter.

CHAPTER III

GENERAL METHOD

APPARATUS

The apparatus consisted mainly of: (i) an enclosed temporal circular maze, (ii) an event recorder, (iii) a Deutsch Spaghetti Gun (Trotter, 1956), (iv) a relay control circuit, and (v) a stop clock. The temporal circular maze was developed by this writer.

THE MAZE

In this section, only some general features of the temporal circular maze are described. The maze, which was of an enclosed type, consisted of two main parts: a circular runway and a radial stem (see Figure 2).

The entire maze was made of stainless steel and had an interior height of four inches and an interior width of 2.5 inches. The floor of the maze consisted of two 7/8 inch steel bars set 1/2 inch apart, and separated by a 1/8 inch gap from the side walls. The bars were so constructed that they could be used as electrodes for the delivery of electric shock if desired. The entire maze was covered with Plexiglas lids.

The top picture of Figure 2 shows the maze viewed from above with its lids removed, and the bottom picture shows the side view of the maze with lids on and a Deutsch Spaghetti Gun in position. The important

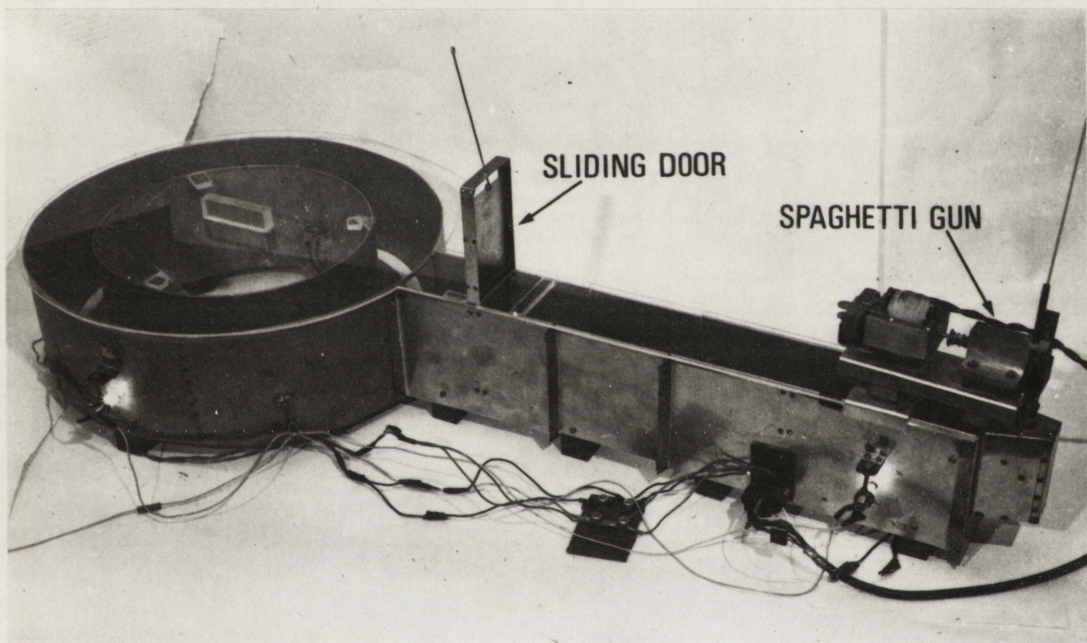
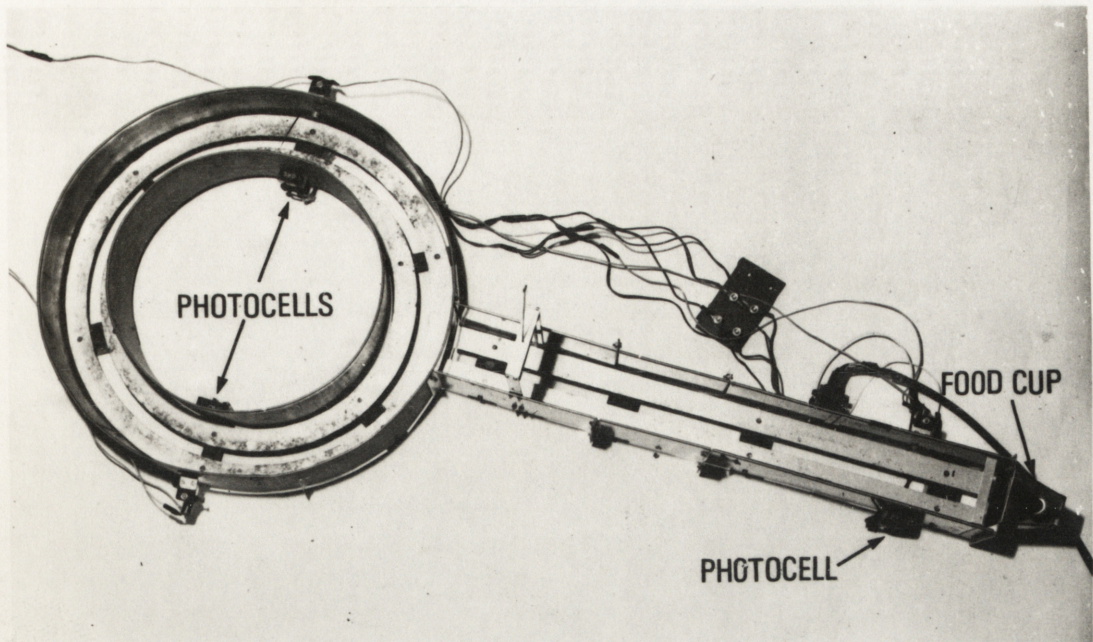


FIGURE 2

Photographs showing some important features of the temporal circular maze; the picture on the top shows an over-head view of the maze with the lids taken away; the picture on the bottom shows a side view of the maze with the lids on and the Spaghetti Gun in position.

features of the maze are: (i) a food cup, (ii) a sliding door, and (iii) three photocells. The food cup was used to receive food reward (a definite length of raw spaghetti, e.g., 1 cm) delivered through the Deutsch Spaghetti Gun. The sliding door, situated in the stem was used as a mechanical means of guiding the animal's response. The three photocells served to collect information of the movement of the animal in the maze for the control circuitry.

THE EVENT RECORDER

The performance of S was registered on a two-channel event recorder. One of the channels was used to register the number of turns being made on each trial and the other was used to register the number of trials being made in each training session (for definition of trials see procedure below). Samples of the record are shown in Figure 3.

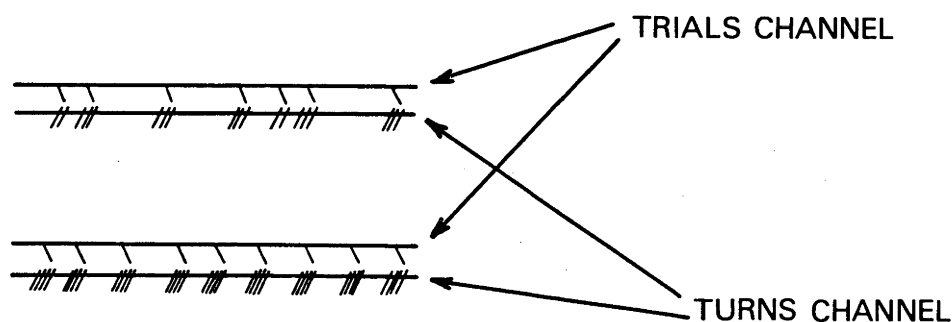


FIGURE 3 Showing samples of the record of S's performance.

THE SPAGHETTI GUN

The Deutsch Spaghetti Gun (shown in the bottom picture of Figure 2) was used for the delivery of food reward. When the Gun was activated, it would deliver a portion of spaghetti of known length into the food cup. The length of spaghetti cut off could be adjusted.

THE RELAY CIRCUITRY

The relay circuitry, which was programmed by Dr J.R. Trotter, was used for automatic recording of S's performance and automatic operation of the Spaghetti Gun. It was so programmed that in order to operate the turn recording pen, both photocells in the circular runway had to be activated (by interruption of the light beam to the photocells) in a row. The first one that was activated served to prim the relay circuitry in such a way that the turn recording pen would operate when the second photocell was activated. It was also programmed in such a way that in order to operate the turn pen for the second time, the photocells had to be activated in the same sequence as on the first turn. This arrangement maximized the possibility that the record taken was always of a complete turn and that every turn within a trial was in the same direction. The trial pen and the Spaghetti Gun were under the control of the photocell in the radial stem. When the beam to this photocell was interrupted, the trial pen would be operated and simultaneously the circuitry was reset and ready for a new trial. If the trial was a correct one, i.e., S had followed the circular runway for the required number of turns (see below), the Spaghetti Gun would be operated

when the beam to this photocell was interrupted. The relay circuitry was situated in a room next to the experimental one.

THE STOP CLOCK

The clock was used to measure the time taken on each training session. It was always started at the moment S ran out of the stem and was stopped at the end of the last trial.

THE TASKS

In this maze situation, S was required, after emerging from the stem, to follow the circular runway for a definite number of turns (e.g., three turns) in one direction, before re-entering the stem for food reward. (It is clear that the stem functioned as a start box at the beginning of a trial and as an end box at the end of that trial). To say that S was required to learn an n-turn task means that S had to make exactly n whole turns before returning to the stem for food. If it made too few or too many turns it received no food.

PROCEDURE

OPERATIONAL DEFINITION OF TERMS USED

A trial. A trial is said to occur when S runs out of the stem, follows the circular runway for at least one complete turn and re-enters the stem. It ends only when S has interrupted the light beam to the photocell in the radial stem.

Guided and free trials. A trial is said to be a guided trial when S is forced to make a correct one. On a guided trial, the sliding door is closed after S has entered the circular runway to prevent it from returning to the stem before the specified number of turns has been run; the door is re-opened when S is about to complete the last turn. A trial is said to be a free trial when there is no interference from the experimenter with S's performance. On a free trial, the sliding door is kept open all the time, and S is free to make either a correct or an erroneous trial.

Training schedules. A training schedule consists of a certain combination of guided and free trials, specified by a formula such as $b \times (cG \ dF)$, which means b repetitions of a block of c guided trials followed by d free trials (b, c, and d being positive integers). For example, a S on a $2 \times (3G \ 6F)$ schedule receives on each training session two repetitions of a block of three guided trials followed by six free trials.

In connection with the training schedules, a G/F ratio was used to represent the ratio of a guided/free trials of a training schedule, e.g., the G/F ratio of $2 \times (3G \ 3F)$ or of $3 \times (4G \ 4F)$ is one, while for $3 \times (4G \ 2F)$ the ratio is two, etc. The G/F ratio was used because it provided a very convenient way for the classification of various training schedules into a family group.

GENERAL PROCEDURE

The training procedure consisted essentially of two stages: a preliminary training and an experimental training.

Preliminary training. The main purposes of the preliminary training were to habituate S to the noise of the operation of the Spaghetti Gun, and to familiarize S to the temporal circular maze. For the first purpose, several methods were tried, each of which is mentioned in connection with the relevant experiment. For the second purpose, S was generally allowed to run the maze for a certain number of trials each day for a certain number of days, and spaghetti was delivered at the end of each trial irrespective of S's performance, i.e., irrespective of the nature of trials being made.

Experimental training. A daily session began by putting S into the stem and ended when it finished the assigned daily trials. No effort was made to control the intertrial interval, and intertrial handling was nil during the course of daily training. The maze is thus virtually a free responding situation. Throughout this study, no punishment, e.g., electric shock, was administered at the end of erroneous trials. On correct trials (i.e., the correct responses made on free trials) and on guided trials, the spaghetti was delivered as soon as S interrupted the light beam to the photocell in the radial stem.

After preliminary training, S was at first trained under an assigned training schedule each day until a predetermined criterion of learning (generally five

consecutive correct runs) was attained. Guidance was generally discontinued when S has reached the criterion of learning, and after reaching the criterion, S's daily session would then consist of a certain number of free trials.

Scores collected. The scores collected generally included:

- (1) time score, i.e., time taken to complete a session,
- (2) number of total trials required to reach the criterion of learning; this score had two components: the number of total guided trials and the number of free trials which included correct and erroneous trials, and
- (3) percentage (and ratio) of correct trials made in each post-criterion session.

SUBJECTS

The Ss used in this study were male white rats obtained from the Animal Breeding Establishment of the Australian National University. Details will be presented on each individual experiment.

CHAPTER IV

CAPACITY OF WHITE RATS IN THE TEMPORAL CIRCULAR MAZE

The main purposes of the following two experiments were to determine:

- (1) if the white rat is able to master any task provided by this maze situation, and if so,
- (2) what is the upper limit of its ability in this maze.

As mentioned in the previous chapter, S was required, after emerging from the stem of the maze, to follow the circular runway for a definite number of turns before re-entering the stem for food. It is thus possible to present S with a series of tasks that require different numbers of turns. It is presumed that a task that requires a large number of turns is more difficult to learn than one that requires a smaller number, e.g., a five-turn task is more difficult than a two-turn one.

In the following two experiments, the general procedure was to train S to learn a two-turn task. When this task was well mastered, S was then required to learn a three-turn task. The experimenter added one turn at a time until S reached the limit of its capacity. During the course of training, some control tests were carried out; however, for the sake of clarity, they are reported separately in the chapter that follows.

EXPERIMENT 1

METHOD

SUBJECTS

The Ss were 12 male white rats aged about 6-7.5 months when the experimental training started. They were housed in groups of six with water freely available, and were generally maintained on a 22-25 hours food deprivation schedule.

APPARATUS

Two temporal circular mazes of different sizes were used. The radii of the inner walls of the circular runways were respectively five inches and 8.5 inches, and the lengths of the radial stems were 20 inches and 21 inches respectively.

PROCEDURE

Preliminary training. All preliminary training was carried out in the five inch maze. Each S received five consecutive free trials each day for about 20 days. Spaghetti was delivered at the end of each trial irrespective of S's performance.

Experimental training. Since this experiment was intended to be exploratory, it is understandable that there would be some variations in treatment among Ss, and that even within one S the treatments might vary from day to day. Whenever possible deviations from the general procedure are reported.

Two-turn task. Training was carried out in the 8.5 inch maze for all Ss except two which were at first trained on a two-turn and a three-turn task respectively in the five inch maze. General treatments for the 12 Ss are summarized below:

- (1) Rats 1 to 5 were trained in the 8.5 inch maze under a 3G 5F 2G 5F 2G 10F 3G schedule each day. However, the schedule was not strictly followed. At the later stage, extra trials were given, usually by successively repeating (2G 10F) pattern or by continuously giving free trials.
- (2) Rats 6 to 10, also trained in 8.5 inch maze, were at first trained with a trial and error method without success; on each session, they were run 20 free trials. Rats 6 and 7 were later randomly selected and trained under the guidance procedure. Detailed procedure and comparison between the effectiveness of trial and error method and the guidance procedure of (1) are discussed in Chapter VI.
- (3) Rat 11, which was used for exploratory study, was trained under an irregular training schedule, the main element of which consisted of continuous repetitions of (5G 5F), and the number of total training trials each day was 40-60. It was trained in the five inch maze.

- (4) Rat 12 was at first trained to learn the three-turn task under a guidance procedure similar to that of rat 11's, but failed to master it. It was then trained on the two-turn task, and like rat 11, was trained in the five inch maze using a similar schedule.

Guidance was generally withdrawn when S was able to make at least nine correct trials out of ten. On the following sessions they were given 25 free trials each day until the performance was very efficient. Rats 1 to 5, 7, 11, and 12, received a total of 10 to 20 training sessions (median: 16) before being trained on the three-turn task. Rats 1 to 5 had also undergone a control test before they were trained on the three-turn task.

Three-turn task. Ten Ss were trained on the three-turn task. Eight of them (rats 1 to 5, 7, 11, and 12) had mastered the two-turn task, while the remaining two (rats 8 and 9) had not. General training schedules was 5G 5F 3G 5F 4G 10F 3G each day. However, daily training was sometimes extended as in the two-turn task when Ss consistently made correct trials. Training was carried out in the 8.5 inch maze except for rat 11 which was trained in the five inch maze. The condition on the withdrawal of guidance was similar to that of the two-turn task. On sessions that followed the withdrawal of guidance, they were usually run as many free trials as possible. Rats 4 and 12 underwent a control test before they were trained on a four-turn task.

Four-turn task. Only two Ss (rats 4 and 12), which had received a total of 13 and 10 training sessions respectively on the three-turn task, were trained on the four-turn task. The general training schedule was 7G 5F 3G 5F 5G 10F 3G, and as with the two- and the three-turn task, exceptions to the schedule were allowed. Training was carried out in the 8.5 inch maze. Rat 12 had undergone a control test before it was trained on a five-turn task.

Five-, six-, and seven-turn tasks. Only rat 12, which had received a total of 51 training sessions on the four-turn task, was trained on these tasks. On the first training session it was run without giving guided trials, the purpose of which was to see if it was able to master the task without further guidance. On the first session of the five-turn task, it ran a total of 22 free trials, and training had to be called off because it refused to continue the maze running (on the last eight trials the intertrial interval range from two minutes to 13 minutes). After the second session, it was generally run under the schedule of continuous repetitions of (3G 3F) block, and the numbers of the daily total trials ranged from 20 to 39. It had received a total of six training sessions and undergone a control test before being trained on the six-turn task.

On the first training session of the six-turn task, it was run a total of 80 free trials, and no guidance was given on the remaining two training sessions on the six-turn task, which was followed by the training on the seven-turn task. It was run 24 free trials on the first training session of the seven-turn task, and was trained

thereafter under a schedule of continuous repetitions of (3G 3F) block. It was eliminated from further training after being trained for five training sessions, because of its apparently disorganized behaviour in the maze.

RESULTS AND DISCUSSION

The results for each S on each task are presented in Table 1. This shows the number of total trials required to reach a criterion of at least 80 per cent correct trials on a training session, and the percentage (and ratio) of correct trials achieved on this criterion session.

On the two-turn task all Ss, except 8, 9, and 10, which were trained under the trial-and-error procedure, were able to master the task. When trained under the trial-and-error method, rats 6 and 10 refused to run the maze (generally they would stay at the food cup for a long period of time); after receiving the specified number of trials, they had to be eliminated from further training. Rats 6 and 7, which failed to master the task after being trained with the trial-and-error procedure, were able to master it when they were trained under the guidance method. Thus it appears that the trial-and-error method was quite ineffective in training the white rat to learn the two-turn task (see Chapter VI for more details).

Nine Ss out of ten trained on the three-turn task were able to master it. It is interesting to note that all eight Ss that had mastered the two-turn task learned the three-turn task, while only one of the two (rats 8 and 9) that had not mastered the two-turn task did.

TABLE 1

NUMBER OF TOTAL TRIALS REQUIRED TO REACH THE CRITERION OF 80 PER CENT CORRECT AND THE PERCENTAGE (AND RATIO) OF CORRECT TRIALS MADE ON THIS CRITERION SESSION

Subject	Total trials to criterion of at least 80% correct	Percentage (and ratio) correct trials on criterion session	Total trials to criterion of at least 80% correct	Percentage (and ratio) correct trials on criterion session
1 2 3 4 5 6 7 8 9 10 11 12	Two-turn task		Three-turn task	
	369	88 (22/25)	491	85 (23/27)
	335	84 (21/25)	448	81 (21/26)
	400	96 (24/25)	435	86 (62/72)
	271	92 (23/25)	256	81 (21/26)
	201	92 (23/25)	494	83 (33/40)
	120 (189) ^a	84 (21/25)	-	-
	682 (370)	76 (45/59)	631	82 (41/50)
		highest		
	633	failed	1050	80 (40/50)
	679	failed	349	failed
	90	failed	-	-
	385	100 (25/25)	427	92 (36/39)
	206	80 (20/25)	315	90 (26/29)
4 12	Four-turn task		Five-turn task	
	208	57 (17/30)	-	-
	1407	80 (32/40)	81	53 (20/38)

^a

The figures in brackets show the total number of trials required to reach the achievement of 84% and 76% correct respectively, when they were trained under the guidance method.

Moreover, it is clear from Table 1 that rat 8 reached the criterion of 80 per cent correct with greater difficulty than the remaining eight Ss. Rat 9 was eliminated when its response rate got very low, i.e., intertrial interval became very long. It is also of some interest to note that, at the very beginning, rat 12 had been trained on the three-turn task for a total of 928 trials without success, before it was trained to learn the two-turn task which it mastered. It was then able to master the three-turn task on the second attempt, i.e., after it had mastered the two-turn task. These results, i.e., failure of rat 9 to master the three-turn task, the failure of rat 12 to master it on the first occasion when it had not learned the two-turn task, and the great difficulty for rat 8 to master the three-turn task, seem to suggest that mastery of the two-turn task is helpful in mastering the three-turn task.

There were no special reasons for giving Ss different numbers of trials on each training session, except that S was generally allowed to run the maze for as many trials as possible and sessions were discontinued when S showed signs of restlessness (e.g., biting, pushing the lid with its head etc.), or when the intertrial interval got longer and longer.

Only rat 12 was able to reach the criterion of at least 80 per cent correct on the four-turn task. Although the number of total trials required to reach the criterion was large (1407), it should be pointed out that evidence of learning occurred quite early. For example, after receiving 166 trials, it was able to make 12 successive correct trials, and the performance thereafter

was very stable. Rat 4 started its training well. However, during this stage of training, it was very liable to get disturbed, either by any noise from outside or by the non-rewarded trials (i.e., errors). It would run the maze sporadically, and would often retrace the stem in between trials. It would run out of the stem, but instead of following the runway as it would in the normal state, would immediately return to the food cup. It was eliminated from further training after being trained for 13 sessions.

As shown in Table 1, rat 12 did not achieve the criterion of at least 80 per cent correct on the five-turn task. However, it should be pointed out at this stage that a control test in which the distance of the runway had been randomly varied, was carried out on the following session. Its performance on that control session was 80 per cent correct (see Chapter V for details).

The result of rat 12 on the six-turn task is interesting. It was able to make 44 correct trials out of 80 on the first training session without being given any guided trial. Twenty-eight of these 44 correct trials were made during the last 40 trials, i.e., it made 70 per cent correct on the last 40 trials. On the following day, the performance was very poor; it ran the maze sporadically. It ran 25 trials in 50 minutes, with 14 of these 25 trials being one-turn errors, and made not a single correct trial. However, on the third session, it was again able to make 40 correct trials out of 70, and 21 of these 40 correct trials were made on the second half. No further training was given on the six-turn

task after this session, and it was trained on the seven-turn task on the next day. Although performance did not reach the criterion of 80 per cent, it was quite apparent from the results of sessions 1 and 3 that it was able to master the six-turn task reasonably well. An interesting feature on the session 3 was that rat 12 had committed a total of 10 seven-turn errors out of 70 total trials (14 per cent), which was the first instance during the entire experiment that such a substantial series of overestimates had been made. However, it should be noted that most of the seven-turn errors had been rewarded. The reason for rewarding the errors was to prevent S from refusing to run the maze. At this stage of training, every non-rewarded trial would make it stay at the food cup for up to five minutes (on the second session there was a record of at least 16 minutes). Raw scores of rat 12 on these three sessions are presented in Appendix Ia, which shows in detail the sequence and characters of trials made.

Rat 12 had been trained on the seven-turn task for five training sessions before the training was discontinued, and it received a total of 107 trials during these five sessions. The performance on these sessions was characterized by the sporadic appearance of trials and predominance of one-turn errors. Each training session lasted for 30-50 minutes, but the number of trials ranged from only 15-28. The one-turn errors ranged from 30 per cent to 87 per cent of the total free trials with a median at 58 per cent; this was quite unusual compared with the performance on the previous tasks, in which the one-turn errors did not usually occur on more than ten per cent of trials.

The results of this experiment have clearly shown that most Ss were able to learn the two-turn, and the three-turn tasks. The results also suggest that method of training is an important factor, and that the trial-and-error procedure used seemed very ineffective. Only two Ss were trained on the four-turn task, and one of them failed to reach the criterion of mastery. However, it was impossible at this stage of the study to determine the actual cause of its failure. Only one S was trained on the five-turn, the six-turn, and the seven-turn tasks, and it failed to master the last of these. Whether the six-turn task is or is not the upper limit of the white rat's capacity in this maze situation needs further study. The design of the present experiment was by no means ideal for determining the capacity limit, for there were too many control tests in the course of training. The vicissitudes of the training procedures in this experiment, and the small number of Ss used for the more advanced tasks, made it difficult to consider the significance of the results in any quantitative fashion. On the whole, this experiment shows that the white rat is able to master up to a six-turn task in this maze situation. Its ability to learn a temporal task seems to have been underestimated.

EXPERIMENT 2

METHOD

SUBJECTS

The Ss were 11 male white rats aged about 15 weeks at the beginning of the experiment. Prior to this experiment, they had been run by this writer in a Hebb-

Williams maze using a procedure very similar to that of Rabinovitch and Rosvald (1951). They were housed in groups of either five or six with water freely available, and were maintained on a 22-24 hours food deprivation schedule while being trained on the two-turn task. During the training on the three-turn and the four-turn tasks, they were given an average of 12 gm per S (either 60 gm or 72 gm for each group) of dry laboratory rat food soon after all Ss in each group had completed their daily training. The daily ration was reduced to 10 gm per S from the beginning of the training on the five-turn task.

APPARATUS

A temporal circular maze was used. The radius of the inner wall of the circular runway was five inches, and the length of the radial stem was 20 inches.

PROCEDURE

Preliminary training. Feeding familiarization. The main purpose of this training was to habituate Ss to the noise of the operation of a Spaghetti Gun, which was used to deliver the food reward. On each day S was placed into a 4 x 4 x 19 inch box with a food cup at one end identical to the one in the temporal maze, and was allowed to stay there until ten pieces of spaghetti (1 cm in length) were consumed. For the first two days four pieces of spaghetti were placed in the food cup before S was introduced into the box, and the remaining six were delivered through the Spaghetti Gun. On the third day, all ten were delivered through the Spaghetti Gun. Some

timid Ss were allowed to have 3-5 more pieces on the third day. The Spaghetti Gun was operated when S's head was over the food cup.

Maze familiarization. After three days of feeding training, all Ss were transferred to the temporal maze, and were given five adaptation trials on each day for seven days. Spaghetti was given through the Spaghetti Gun at the end of each trial irrespective of S's performance. Besides familiarizing S with the temporal maze, the other important function of this training was to reduce S's tendency to retrace the stem, i.e., the tendency to return immediately to the food cup after running out of the stem. It was only at the end of this training that S would follow the runway readily after emerging from the stem.

Experimental training. The experimental training consisted of two main stages. In the first stage S was trained under the guidance procedure until a criterion of five consecutive correct trials was reached. The second stage began when S had reached the criterion and there was no guidance in this stage.

Two-turn task. All Ss were trained daily under a 2 x (4G 4F) schedule. However, if S was able to make three consecutive correct runs, two extra free trials were given, and if the first of these two was correct a further trial was given. Thus on no occasion was S allowed to run more than seven consecutive free trials during this stage of training. Guidance was discontinued when S reached the criterion of five errorless runs, and at the criterion session, 20 extra free trials were run

immediately following the fifth criterion trial. After reaching the criterion, they were given six to 16 post-criterion sessions, each of which consisted of 30 free trials, before they were trained on the three-turn task. The number of post-criterion sessions depended upon the stability of S's performance.

Three-turn task. The training procedure was similar to that of the two-turn task, except the manner of conducting the guided trials. On all guided trials except the first two of each session, the sliding door was closed when S was about to finish the second turn, and on the first two guided trials of each session, it was closed, as in the two-turn task, soon after S had entered the runway. After reaching the criterion, five Ss were given 12 to 19 post-criterion sessions before a control test was carried out. After the control test each of these Ss ran a further post-criterion session before it was trained on the four-turn task. Two Ss that were not used for the control test, received 15 and 25 post-criterion sessions respectively before the four-turn task training started. Again, each post-criterion session consisted of 30 free trials.

Four-, five-, six-, and seven-turn tasks. Training procedure was basically similar to that of the two-turn task, except: (i) on the first training session of each task, S at first ran at least 26 free trials before a (4G 4F) block was given, and (ii) if S was able to make two or more (but less than five) errorless runs, extra free trials were run until four consecutive errors occurred. The purpose of giving at least 26 free trials right at the beginning of each new task was to determine

if and on which task S could reach the criterion of five errorless trials without receiving any guided trial. As in the three-turn task, on most of the guided trials the sliding door was closed when S was about to complete the second last of the required turns; and on the first two guided trials of each training session, it was closed soon after S had entered the circular section of the maze. The number of trials in each post-criterion session ranged from 30 to 60 instead of being fixed at 30 as in the two- and the three-turn tasks. Extension of the number of trials was necessary especially on the early occasions of training, in which correct responses would appear late. Six Ss received six to 11 post-criterion sessions on the four-turn task before proceeding to the five-turn task. Three Ss, which had 11, 16, and 17 post-criterion sessions on the five-turn task respectively were trained on the six-turn task. Only one S which had 31 post-criterion sessions on the six-turn task was trained on the seven-turn task. Subjects were eliminated from the more advanced tasks when they either did not master the preceeding task, or their post-criterion performance was not particularly stable.

RESULTS AND DISCUSSION

TOTAL TRIALS TO CRITERION

Table 2 presents the number of total trials required to reach the criterion of learning for each S on each task. The numbers of total trials run by Ss that failed to reach the criterion are also presented. It is clear from Table 2 that all Ss trained on the two-turn task

TABLE 2
NUMBER OF TOTAL TRIALS REQUIRED TO REACH THE CRITERION
OF FIVE ERRORLESS RUNS FOR EACH SUBJECT ON EACH TASK

Subject	Task					
	Two-turn	Three-turn	Four-turn	Five-turn	Six-turn	Seven-turn
13	340	(716) ^a	-	-	-	-
14	551	380	209	130	-	-
15	468	656 ^a	43	70	53 ^b	-
16	822	(368) ^a	-	-	-	-
17	366	949 ^a	(60) ^a	-	-	-
18	1116	(208) ^a	-	-	-	-
19	292	169	26 ^c	45	51 ^b	- ^b
20	733	465 ^a	111	79	6	16
21	261	(797) ^a	-	-	-	-
22	357	633	33	180	-	-
23	1403	380	89	-	-	-

^a The number of total trials run by S before it was eliminated from further training.

^b Without guidance.

^c This S was directly trained under the 2 x (4G 4F) schedule at the beginning of this task; it did not receive 26 free trials at the beginning of training as described in the text.

were able to reach the criterion. However, the number of trials required to reach the criterion varied greatly among Ss (ranging from 261 to 1403).

Of the 11 Ss trained on the three-turn task, seven were able to reach the criterion while the remaining four did not. By the time these four Ss were eliminated from further training, all of them had developed a strong tendency to commit one-turn errors on most of the free trials, which suggests they might have learned the 'wrong set' on guided trials, i.e., they learned to enter the stem whenever it was open. The performance of rats 13 and 21 was of some interest. They were the third and the first to master the two-turn task, yet they failed the three-turn task even after being extensively trained. Furthermore, when they were put back to the two-turn task again, the tendency to commit one-turn errors quickly disappeared. Without any guidance, they were able to run the maze efficiently after two sessions of further training on the two-turn task. On the third session rat 13 was actually able to make 23 correct trials out of 30, and rat 21 made 27 correct out of 30, and they were able to maintain this efficiency on the following three sessions. When they were again trained on the three-turn task, the tendency to commit one-turn errors appeared again after, respectively, four and nine sessions of guided training. In Experiment 1, all eight Ss that had mastered the two-turn task beforehand were able to master the three-turn task with less difficulty (see results on Table 1; the scores should have been smaller had the criterion of five consecutive correct trials instead of the criterion of at least 80 per cent correct

been adopted). One possible explanation for the poor performance of some Ss in this experiment might be the training schedule employed. This may have facilitated the development of the 'wrong set', mentioned above.

Six out of the seven Ss that were trained on the four-turn task reached the criterion. After being run for two training sessions, rat 17 was eliminated from further training because of the high proportion of one-turn errors committed, which again suggest a breakdown of behaviour. Data for those Ss that succeeded show that the numbers of trials to criterion reduced sharply when compared with their scores on the two-turn and the three-turn tasks. None of these Ss was able to master the task without guidance.

All five Ss trained on the five-turn task were able to reach the criterion with small amounts of training (see Table 2). For rats 14, 19, and 20, the numbers of trials to criterion were even smaller than their scores on the four-turn task; this was not so for rats 15 and 22, however. None of the four Ss that had received at least 26 free trials at the beginning of the first training session was able to reach the criterion without guidance. Some guided trials were still necessary for this task.

On the six-turn task, all three Ss trained on it were able to reach the criterion. It is interesting to note that rats 15 and 20 were able to reach the criterion without being given any guided trial. For rat 15, the correct trials appeared quite consistently at the end of the first 26 trials, and it was able to make

eight correct trials out of ten between trials 26 and 35. Its response sequence on this session is presented in Appendix Ib. Rat 20 was able to make six consecutive correct trials after receiving only six free trials. The experimenter was quite surprised by this quick learning and wondered whether this S had used some other external cues. The only possible source of distinctive cues, if any, was the noise of the relay circuitry. So the circuitry was put out of action by turning off the light beam to the photocells at the end of the sixth correct trial. Rat 20 still performed successfully thereafter (for details see Chapter V). Its response sequence on this session is also shown in Appendix Ib. It is interesting to note that in Experiment 1, rat 12 was also able to perform very efficiently without any guidance on the six-turn task, but failed to do so on the five-turn task, on which some guidance was still needed. Further studies are needed to determine whether this interesting feature has any theoretical significance for comparative studies.

Only rat 20 was trained on the seven-turn task and it was also able to reach the criterion without guidance. The sequence of its responses on this session is also presented in Appendix Ib.

On the whole, the results in Table 2 show two interesting features:

- (1) the number of trials required to the criterion of learning reduce sharply on the tasks following the four-turn one,

- (2) on the six-turn task, two Ss were able to reach the criterion without guidance.

These features, which had been noted in Experiment 1, seem to have two important implications:

- (1) they seem to suggest that these Ss developed, during the course of training, some type of learning set which enabled them to cope more adequately with the later more difficult tasks (see post-criterion performance below), and,
- (2) the entire course of learning the tasks can be separated roughly into two stages: an initial stage in which a trial-and-error procedure would be very ineffective if not impossible, followed by a stage where the trial-and-error procedure would be sufficient. It has been shown in Experiment 1 that the trial-and-error method was very ineffective in training the white rat to learn the two-turn task (details see Chapter VI). Observation of S's performance seems to suggest that this would also be the case on the three-turn task. While it was not possible to determine conclusively from the results of the present and the previous experiments on which task the trial-and-error procedure would be successful for the white rat, they suggest it would be either the four-, the five-, or the six-turn task. Presumably this would have some connection with the intelligence of the animals studied.

POST-CRITERION PERFORMANCE

The percentages (and ratios) of the correct trials made in the post-criterion sessions for all Ss on the tasks they mastered (i.e., reached the criterion of five errorless runs) are summarized in Table 3. It is clear from this Table that there was a gradual decrease in the percentages of correct trials as the task became more advanced. This may be viewed as empirical evidence for the presumption mentioned in the introduction section of this chapter, namely that a task which requires a large number of turns is more difficult than one that requires fewer.

On the four-turn task, rat 23 was eliminated from further training after one post-criterion session because of its poor performance. On the five-turn task rats 14 and 22 were also eliminated from further training after being run for three and seven post-criterion sessions respectively, again because they performed poorly on these sessions. On the six-turn task, rat 15 was able to perform very well at the earlier sessions, but training was discontinued after it was run for 25 sessions. Its performance seemed to have deteriorated (judging from the increased proportion of one-turn and two-turn errors) in the later sessions. Rat 19's performance on the six-turn task was filmed after receiving 17 post-criterion training sessions. It was then eliminated from the seven-turn training. On the seven-turn task, training on rat 20 was discontinued after it was run for 13 post-criterion sessions, because it seemed to have developed a tendency to commit one-turn errors, which suggested the disorganization of behaviour (see the results on types of

TABLE 3

MEDIAN PERCENTAGE (AND RATIO) OF CORRECT TRIALS MADE ON THE POST-CRITERION SESSIONS FOR EACH SUBJECT ON EACH TASK

Subject	Task					
	Two- turn		Three- turn		Four- turn	
	Mdn	Range	Mdn	Range	Mdn	Range
13	87 (26/30)	80-97	failed	-	-	-
14	83 (25/30)	40-97	73 (22/30)	47-90	67 (20/30)	50-83
15	83 (25/30)	70-90	80 (24/30)	67-93	63 (19/30)	25-78
16	83 (25/30)	57-90	failed	-	-	-
17	87 (26/30)	50-100	67 (20/30)	14-87	failed	-
18	83 (25/30)	53-97	failed	-	-	-
19	90 (27/30)	80-97	90 (27/30)	73-100	83 (50/60)	62-93
20	90 (27/30)	77-93	73 (22/30)	34-93	60 (18/30)	40-77
21	93 (28/30)	70-97	failed	-	-	-
22	90 (27/30)	77-100	73 (22/30)	57-83	63 (19/30)	46-80
23	87 (26/30)	13-90	73 (22/30)	17-90	26 (9/35) ^b	-

Subject	Task					
	Five- turn		Six- turn		Seven- turn	
	Mdn	Range	Mdn	Range	Mdn	Range
13	-	-	-	-	-	-
14	4.5 (2/44)	0-17 ^a	-	-	-	-
15	62 (31/50)	22-80	36 (18/50)	10-80	-	-
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	-	-	-	-	-	-
19	73 (22/30)	57-90	37 (20/54)	20-66	-	-
20	56 (28/50)	22-70	42 (21/50)	23-64	16 (8/50)	8-28
21	-	-	-	-	-	-
22	28 (9/32)	7-57	-	-	-	-
23	-	-	-	-	-	-

a. only three post-criterion sessions were run.

b. only one post-criterion session was run.

responses made below). The deterioration of performance and the development of the tendency to commit one-turn errors might be due to factors such as frustration caused by the frequent errors, increasing difficulty of the tasks, ageing of Ss, malnutrition due to long periods of under feeding, etc.

It is impossible to make statistical evaluations of S's performance, because the exact probability of success on each trial can not be determined. However, it seems quite evident from the results in Table 3, together with the data on the longest errorless runs Ss were able to make on each task (see Table 4), that for some Ss genuine learning has taken place in tasks up to the six-turn one. On the other hand, the post-criterion performance of rat 20 on the seven-turn task was so poor that it was difficult to decide whether learning had occurred, although it was able to reach the criterion of five errorless runs. There are, however, some considerations which might help in evaluating rat 20's performance. Examination of the data of all Ss on all tasks showed that generally a given task that required n turns, the number of types of responses possibly made is $n+1$. For example, on the three-turn task, four types of responses could be made: one-turn, two-turn errors (underestimation), three-turn correct trials, and four-turn errors (overestimation) (see next section for more details). The data also showed that overestimation errors were very seldom committed, and on no occasion did a S commit more than three consecutive overestimation errors. Now consider the performance of rat 20. On the six-turn task, the proportions of seven-turn errors committed by it

TABLE 4

THE LONGEST ERRORLESS RUNS EVER MADE BY EACH SUBJECT ON EACH TASK THAT IT MASTERED. FIGURES IN BRACKET SHOW THE NUMBERS OF TRIALS RUN IN THE SESSION IN WHICH THE LONGEST RUNS WERE MADE

Subject	Task					
	Two-turn	Three-turn	Four-turn	Five-turn	Six-turn	Seven-turn
13	29 (30)	-	-	-	-	-
14	29 (30)	27 (30)	18 (30)	5 (43)	-	-
15	25 (30)	27 (30)	18 (30)	18 (50)	17 (50)	-
16	21 (30)	-	-	-	-	-
17	30 (30)	21 (30)	-	-	-	-
18	29 (30)	-	-	-	-	-
19	29 (30)	30 (30)	27 (30)	21 (30)	11 (32)	-
20	27 (30)	25 (30)	11 (30)	19 (50)	10 (50)	8 (50)
21	28 (30)	-	-	-	-	-
22	30 (30)	18 (30)	15 (30)	7 (37)	-	-
23	26 (30)	21 (30)	8 (40)	-	-	-

range from 0 per cent to eight per cent of the total daily trials (median: 2 per cent); on no occasion did it make more than two consecutive overestimation errors (most of them were rewarded). When it was trained on the seven-turn task, however, it was able to make eight per cent to 28 per cent correct out of 50 daily trials (median: 16 per cent). The increase seems very substantial. Furthermore, during the post-criterion sessions, it was able to make eight consecutive correct trials on one occasion. These two results seem to suggest that when the task was shifted from six turns to seven, some significant behavioural change did take place.

It is an interesting problem whether the performance of these rats on the six-turn and the seven-turn tasks would have been improved or the limit of their capacity raised, had guidance being given during these inefficient sessions. However, this problem is not investigated in this study.

TYPES OF RESPONSES MADE

In order to give a clearer picture of S's behaviour in the maze the data on the types of responses being made on each task during the pre-criterion and post-criterion stages are summarized below.

Pre-criterion training. Table 5a shows the median percentages of each type of response (guided trials excluded) being made on each task on all sessions for Ss that were able to reach the criterion of learning. It is quite clear from this Table that: (i) overestimation errors were negligible, although some Ss did commit them, and (ii) for a given task, the dominant trials were those one..

TABLE 5a
MEDIAN PERCENTAGES OF THE TYPES OF TRIALS MADE DURING THE ENTIRE PRE-CRITERION TRAINING
FOR ALL SUBJECTS THAT LEARNED THE TASKS

Task	No. of Ss trained	Type of trials							
		One-turn		Two-turn		Three-turn		Four-turn	
		Mdn	Range	Mdn	Range	Mdn	Range	Mdn	Range
2-turn	11	87	83.5-94.5	13	5.1-16.5	0	0-0.7	0	0- 1.4
3-turn	7	10.6	1.2-19.2	71.7	66.5-75.8	17.4	13.8-26.9	0	0- 1.2
4-turn	6 ^a	4.9	0-10.3	10.3	1.2-20.7	58.6	53.3-64.3	26.2	14.3-39.7
5-turn	5	0.8	0- 4.4	2.3	0- 3.4	16.2	6.8-20.9	52.1	45.3- 61
6-turn	3	0	0-4	0	0-4	0	0-4	12.5	8-33.3
7-turn	1	12.5	-	0	-	0	-	12.5	-

Task	No. of Ss trained	Type of trials							
		Five-turn		Six-turn		Seven-turn		Eight-turn	
		Mdn	Range	Mdn	Range	Mdn	Range	Mdn	Range
2-turn	11	-	-	-	-	-	-	-	-
3-turn	7	-	-	-	-	-	-	-	-
4-turn	6 ^a	-	-	-	-	-	-	-	-
5-turn	5	27.1	23.9-36.7	0	0- 3.9	0	0- 0.8	0	0- 0.8
6-turn	3	50	46-56.4	36	16.7-30.8	-	-	-	-
7-turn	1	25	-	50	-	-	-	-	-

a. The higher score of the middle two scores is presented.

turn less than the required; e.g., for the four-turn task, the three-turn errors were the dominant responses during this stage of training. Table 5b shows the types of trials made by Ss that failed to reach the criterion of learning. A feature differing markedly from those of Table 5a was the sharp increase in the proportions of the one-turn errors, which dominant Ss' behaviour at the later stage of training. The tendency to commit one-turn errors was so strong and consistent that it seems justifiable to use it as an index of the breakdown of S's behaviour (see above on the 'wrong set').

Post-criterion performance. Table 5c shows the proportion of the types of trials made for each task during the post-criterion sessions. Three features are prominent: (i) for a given task that require n turns, the possible numbers of types of trials is $n+1$, except on the six-turn task; (ii) the most frequent errors were those one turn less than the required number, and other errors occurred very seldom; and (iii) the dominant trials at this stage were the correct trials, except on the seven-turn task in which the dominant trials were the one-turn error type.

It should be noted that the proportions mentioned above represent only an overall picture. During the course of training, the proportions changed from stage to stage. For example, in the pre-criterion stage for Ss that were able to reach the criterion, the correct trials were concentrated in the very latest stage of acquisition (generally the last three or four sessions); for Ss that failed, the one-turn errors were concentrated in the later stage of training. In the post-criterion

TABLE 5b
PERCENTAGES OF THE TYPES OF TRIALS MADE DURING THE PRE-CRITERION TRAINING
FOR EACH SUBJECT ON THE TASK THAT IT FAILED TO MASTER

Subject	Task on which it failed	No. of sessions run	Types of trials				
			One-turn	Two-turn	Three-turn	Four-turn	Six-turn
13	3-turn	43	51.2	43.6	5	0.3	0.3
16	3-turn	23	43	55.4	2.6	-	-
18	3-turn	19	44.2	54.8	1	-	-
21	3-turn	50	40.8	52	6.9	0.3	-
17	4-turn	3	37.5	13	45.3	4.2	-

sessions, the percentages of the correct trials would be higher in the later sessions than in the earlier sessions except for Ss that failed to attain a relatively stable performance.

The main findings of this experiment are:

(1) The white rat seems capable of mastering tasks involving ones up to six turns, using this maze and training procedures. However, one S was able to solve the seven-turn task with limited success.

(2) As the tasks advanced, the number of trials required to reach the criterion of five consecutive correct trials reduced sharply, and two Ss were able to reach the criterion without guidance on the six-turn task (see Table 2). The results seem to suggest that during the course of training these Ss had developed some type of learning set which enabled them to cope more efficiently with the later more difficult tasks. It should be noted that in ordinary learning set studies, the successive problems presented to the animals are generally of comparable difficulty, while in this maze situation the difficulty of the tasks seems to increase as they advanced.

(3) The increasing difficulty of the more advanced tasks was reflected in the number of Ss that could master the more advanced task, in the performance scores on the post-criterion sessions (see Table 3), and in the scores on the longest errorless runs on each task (see Table 4).

(4) Subjects that had to be eliminated from further training had developed a strong tendency to commit one-turn errors, which was viewed as an index of the

breakdown of Ss' behaviour (see Table 5b). This tendency could be 'suppressed' by putting Ss back to its previous task.

(5) For successful Ss, the commonest types of trials made on a given task that required n turns were n -turn trials (correct ones) and $(n-1)$ -turn trials (underestimation errors). Other types of trials occurred relatively infrequently (see Tables 5a and 5c).

DISCUSSION

The white rat's ability to respond to a temporal sequence without the presence of any differential sensory stimuli was at first studied by Hunter (1920) in a double alternation temporal maze (see Chapter II), with negative result. Although it was found in a later study (Hunter and Nagge, 1931) that by giving differential sensory cues which were then gradually eliminated, some Ss were able to learn the required sequence of response with great difficulty, they were unable to extend their performance beyond the LLRR sequence on which they had been trained. Studies of the double alternation problem in organisms higher than the rat (see Chapter II) suggest that these animals seem to be able to solve the problem on the basis of symbolic processes, although they (except monkeys) were unable to extend beyond the response sequence (e.g., LLRR) on which they were trained. The limited success of these animals, especially the rat, on this problem limits its usefulness as a technique for extensive studies of the ideational processes in learning, although the technique has previously been regarded as

one of the best methods for testing the presence of these processes in animals.

The results of the present experiments show that the white rat's ability to learn problems of a temporal nature seems to have been underestimated. It is quite capable of solving tasks in the temporal circular maze at least up to six turns. Thus the maze used in this study would appear to have considerable advantages over the double alternation temporal maze and may prove a useful tool for studying complex behaviour in animals.

Other useful features of the maze are: (i) the successful performance seems to be 'independent' of exteroceptive cues, (ii) only simple motor activity, i.e., locomotion, is required, (iii) handling of animal during each training session is minimal, and, (iv) there is great scope for automation for experimental operations. These features suggest possible applications of this maze to other problems, e.g., in comparative studies and studies of the effects of drugs on animal behaviour.

One of the basic questions involved in this maze situation as well as in the double alternation problem is how the animal is able to execute the correct responses without the aid of exteroceptive cues. For example, when doing a three-turn task in the temporal circular maze, what makes it possible for S to follow the runway for exactly three turns, rather than two or four, before re-enters the stem for food reward? It is quite apparent from the experimental setting that there are no differential sensory cues at the choice point to be associated with the responses of entering the stem or continuing the circular runway for another turn. The

required differential responses depend upon the numbers of previous turns which follow one another in temporal sequence only. Does the white rat solve the tasks in this maze situation on the basis of symbolic processes, or more specifically is it counting? This problem will be dealt with in the next chapter.

CHAPTER V

CAN RATS COUNT?

It has been shown in the previous chapter that the white rats were able to learn tasks in the temporal circular maze up to at least six turns. In this maze situation, S was forced to follow the same circular runway for a definite number of turns. Since the stimuli associated with the choice point (i.e., the junction between the circular runway and the radial stem) are identical from turn to turn, it was impossible for these same stimuli to provide S with distinctive cues for its alternative response, i.e., either to go round the circular runway once more or to enter the radial stem. Since the task involved only a temporal sequence, and it was not possible for S to use exteroceptive cues inside or outside the maze, nor proprioceptive stimuli, for its successful performance, an interesting problem arises as to how the white rat was able to follow the runway for the exact number of turns before re-entering the stem.

Since the distance of the circular runway was constant during the entire course of maze training, there was a possibility that successful performance might be based on distance cues, cumulative sensory feedback of running activities, or time. But if these were to be varied and S was still able to retain the acquired behaviour, and furthermore there was evidence that S was not aided by other exteroceptive cues, such as those from the Experimenter or from the relay circuitry, then the

view that successful performance was based on ideational processes functionally equivalent to counting would be strengthened.

It is apparent that the processes under investigation can not be directly observed but must be inferred, and the evidence will be indirect. The method adopted is then to determine as many cues as possible that were not used by S for its successful performance. The control tests reported in this chapter were devised for this purpose, namely to determine what cues were not used by the white rat to solve the problems in this maze.

It has been mentioned that every control test except one was actually a continuous part of the experiments of the previous chapter, but each was separately reported for the sake of clarity. Except where otherwise specified, each S's identity number in this chapter corresponds to that in the previous one. The control tests were started only when S's performance was very efficient and stable on a given task. They were carried out in the order of presentation here.

CONTROL TEST 1

METHOD

SUBJECTS

Rats 4 and 11 were used in this control test.

APPARATUS

A modified temporal circular maze similar to the one shown in Figure 4 was used for this control test. The only difference was that the radius of the inner

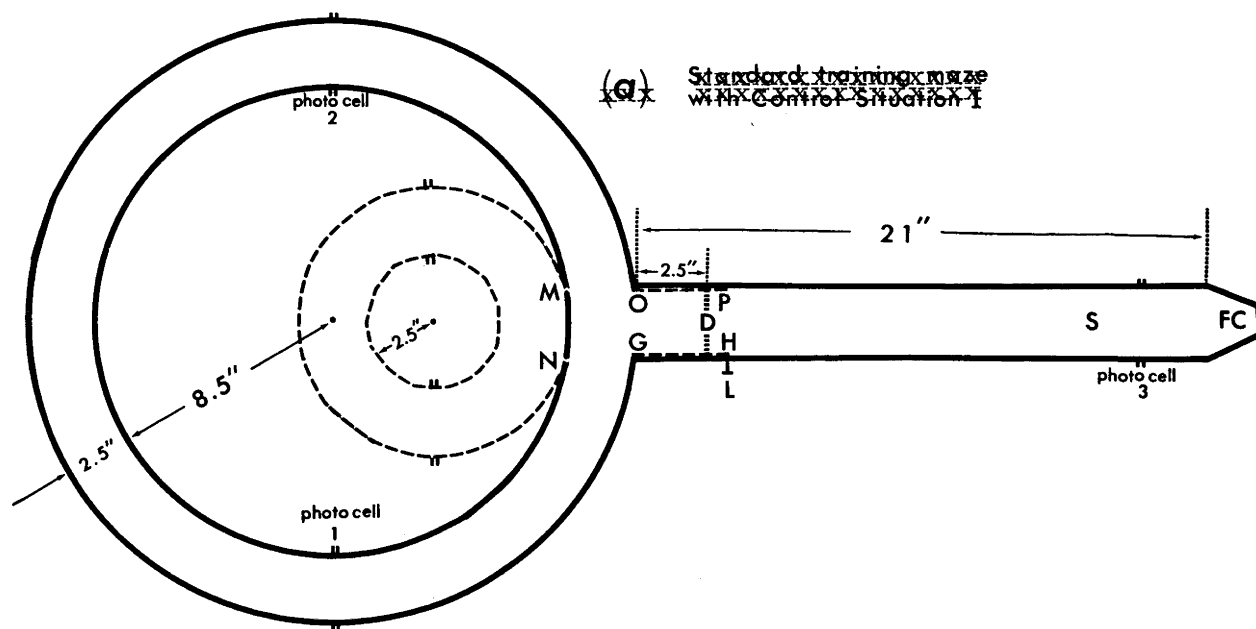


FIGURE 4

Ground plan of a control maze. FC, food cup; S, approximate spot at which Subject was put into the maze; D, vertical sliding door for guiding Subject's response; L, lever to slide out two concealed walls (OP and GH) to points M and N; MN removable wall permitting entrance to the small circular runway.

wall of the small runway (shown in broken lines) was five inches instead of 2.5 inches as shown in the Figure. The apparatus was so constructed that the large maze could be changed to a small one in the following way:

- (1) operation of lever L slides out the concealed walls (OP and GH) to the points M and N, and thus extends the stem and at the same time blocks the access to the large circular runway;
- (2) vertical removal of wall MN permits entry to the small circular runway.

The circular runway can thus be changed from large to small and back again at will.

PROCEDURE

The principal procedure of this control test was to run Ss, on the same session, alternately in the large and the small mazes. Namely:

- (1) S ran at first in one maze for an arbitrary number of trials,
- (2) while S was eating the spaghetti at the food cup, the maze situation was quickly changed and S was allowed to run for certain further trials;
- (3) the maze situation was changed back again while S was eating the spaghetti, and it ran a few trials in the original maze before the situation was changed again, and so on.

Because of the time needed for adjustment, the maze situation could be changed only when S had made a correct trial and was busy eating at the food cup.

The radii of the circular runways were selected so that the ratio of their lengths was 17:10, i.e., the distance run in two turns of the large circular runway would be approximately equal to the distance run in three turns of the small runway. It was assumed that if Ss were able to perform efficiently in these sessions, irrespective of the changes of the circular runways, then the results would support the view that they are not using distance cues, or cumulative sensory feedback due to running a constant distance.

RESULTS AND DISCUSSION

RAT 4

For this S the control test was carried out on the two-turn task. Prior to this test, it was trained in the large maze of the control apparatus to learn the two-turn task. The control test began following the session in which S reached the criterion of at least 80 per cent correct (see Chapter IV). It was run for five control sessions.

Following are some abbreviations used for the presentation of the results: C for correct trials; E(1), E(2), E(3), etc., for one-turn errors, two-turn errors, three-turn errors, etc.; thus 2E(1) 3C 1E(3) means two consecutive one-turn errors followed by three correct trials followed by one three-turn error and so on. The

results on the first two control sessions are presented below:

Stage	Maze situation	Character and sequence of trials
FIRST CONTROL SESSION:		
1	Large (L)	1E(1) 4C
2	Small (S)	5E(1) 1C
3	L	1E(1) 1C
4	S	2E(1) 1C
5	L	12E(1) 1C 7E(1) 1C 1E(1) 1C 15E(1) 2C
6	S	3E(1) 4C
7	L	5E(1) 1E(3) 1C 5E(1) 12C
SECOND CONTROL SESSION:		
1	L	2E(1) 1C 1E(1) 21C
2	S	1E(3) 3C
3	L	3C
4	S	2C
5	L	1C
6	S	1C
7	L	3C
8	S	1C
9	L	2C
10	S	2C

The results in the remaining three sessions were similar to those on the second control session. It is clear from the results that S was disturbed on the first control session, but was able to perform very efficiently on the second session irrespective of the frequent changes of the maze situation. It made 39 correct trials

out of 44 on the second session. It is interesting to note that on stage 2 of the second session, one E(3) was committed when the maze was changed from the large to the small. However, examination of the data suggests that this incident could not be taken as evidence for the view that this S's performance was based on distance and cumulative sensory feedback of running activities. In the fourth control session, which started with the small maze, another E(3) was committed in the small maze; however, this E(3) was the very first trial of this session. In the fifth control session, one more E(3) was committed in the large maze, and this occurred when the maze situation was changed from small to large.

RAT 11

For this S the control test was carried out on the three-turn task. Prior to the control test it had been trained in the five inch maze (already mentioned in Experiment 1 of Chapter IV) for a total of 933 trials on this task. Thus the small circular runway of the control apparatus was the customary one, but the stem and the large circular runway were entirely new to it. A total of 12 control sessions were run. The characters and sequence of trials made in three control sessions are as follows:

Stage	Maze situation	Character and sequence of trial
FIRST CONTROL SESSION:		
1	S	3E(1) 1E(19) 1E(8) 1E(6) 1E(2) 1E(1) 1E(5) 2E(4) 1C 1E(2) 3C 1E(2) 10C
2	L	1E(1) 1E(2) 1E(1) 1C 1E(2) 1E(1) 1E(2) 1E(1) 1E(2) 1C
3	S	1E(1) 1E(2) 1C 2E(2) 1E(4) 2C 1E(2) 4C
4	L	1C 4E(2) 1C 1E(2) 1C 4E(2) 1C 5E(2) 1C
5	S	1C 1E(2) 1E(4) 3C
6	L	4E(2) 1C 1E(2) 5C
7	S	3C
8	L	1C 1E(2) 1C 1E(2) 1C
SECOND CONTROL SESSION:		
1	L	1E(1) 1E(2) 1E(1) 1C 7E(2) 2C 1E(2) 1C 1E(2) 18C 2E(2) 3C
2	S	4E(2) 16C
3	L	1E(2) 1C 2E(2) 16C
4	S	9C 1E(2) 1C
5	L	1C 1E(1) 1E(2)
FOURTH CONTROL SESSION:		
1	S	1E(1) 1C 2E(2) 5C
2	L	7E(2) 1C 1E(2) 4C 1E(2) 5C
3	S	1E(4) 5C
4	L	2C 1E(2) 4C 1E(4) 4C 1E(5) 5C
5	S	5C
6	L	5C
7	S	5C
8	L	1E(4) 5C

Stage	Maze situation	Character and sequence of trial
9	S	5C
10	L	1E(2) 2C 1E(2) 5C
11	S	5C
12	L	1C 2E(2) 1C 1E(2) 4C 1E(2) 5C
13	S	5C
14	L	5C
15	S	5C
16	L	1E(2) 1C 1E(2) 3C

The performance on the third control session, which started with the large maze and involved ten stages, was less efficient than that on the fourth but more efficient than that on the second session. The results on the remaining sessions were similar to those on the fourth session except that the numbers of trials on each stage were generally smaller. For example, in the last control session, S received a total of 31 trials which involved 17 stages, and 28 out of these 31 trials were correct.

It is clear from S's performance on stage 1 of the first control session that it was greatly disturbed (or confused!) by the change to the new stem, although the circular runway was the customary one. Its performance improved slightly at the later part of the first control session. From the fourth session, it was able to perform as efficiently as in the standard training maze, irrespective of the changes of circular runways. Its performances on the last three sessions in the standard training maze were 92 per cent, 80 per cent and 80 per cent correct respectively.

The results of rats 4 and 11 on this control test show that after a short period of disturbances, they were able to perform very efficiently even though the distance of the runway was changed frequently in each control session. One could not conclude from the initial disturbance that they were unable to transfer their acquired behaviour from one maze to the other that differs in the length of the circular runway. For there are certainly many novel conditions in the new situation that may work against the transfer. Examination of the character of the errors committed, which were mainly underestimation errors, also does not suggest the hypothesis that cues due to distance were the operative ones.

This control test was not used for other Ss, because the operations required for changing the maze situations were not mechanically satisfactory, especially the operation of the wall MN, which would cause a great deal of noise, and sometime even could not be done quickly enough. In order to overcome some of these technical difficulties the following control procedure was adopted.

CONTROL TEST 2

METHOD

SUBJECTS

Rats 1 to 5, 8, 11, and 12 were used in this control test.

APPARATUS

As shown in Figure 4.

PROCEDURE

The main control procedure involved the following two steps:

- (1) S was first run in the large maze (the customary one) for 20 to 30 trials, and
- (2) while it was eating spaghetti at the food cup the maze situation was quickly changed as described in Control Test 1, to the small one (2.5 inch) and then the subsequent performance in this maze was observed.

This control test was carried out on the two-turn and the three-turn tasks. Only one control test was carried out for each S.

The rationale for this control test was similar to that of the previous one, namely, if Ss were able to retain their acquired habits in the small maze, then it would support the view that cues due to distance, or cumulative sensory feedback of running activities were not necessary for successful performance. In this control test, the radius of the small runway was reduced to 2.5 inches to make the difference between the distance travelled in the large circular runway and in the small one larger. Again, if S failed to transfer its acquired behaviour to the new maze, this would not mean that the above mentioned cues were used, unless there were clear evidence that the errors committed were overestimated ones, e.g., four-turn errors.

RESULTS AND DISCUSSION

The results are presented in Table 6, which shows the percentage (and ratio) of correct trials made in the large maze (the customary one) and in the small maze (the control one). It is clear from these data that on the two-turn task, rats 2 and 4 were able to retain their habits when transferred from the large maze to the small one. For rat 3, overall performance was not very efficient when compared with its performance in the customary maze; however there was evidence that it was able to transfer its acquired habits to the new maze. From 25th trial, it made ten consecutive correct trials and committed only two one-turn errors in the last 15 trials. On the three-turn task, rats 4 and 11 which had been used in Control Test 1, were able to retain their acquired habits in the small maze, although the percentages of correct trials dropped in the control maze.

For those rats that were unsuccessful, the nature of the errors committed in the new maze provided no support for the view that distance and cumulative sensory feedback of the running activities were the operative cues. Thus for the two-turn task, the errors were entirely one-turn responses. For the three-turn task they were either one-turn errors or two-turn errors, and on only one occasion did rat 4 commit a four-turn error (see Table 7). This result is opposite to that expected if the above cues were the crucial ones. It is also interesting to note that for rats 8 and 12, the proportion of one-turn errors increased sharply in the small maze as compared with the performance in the customary one (Table 7).

TABLE 6
PERCENTAGE (AND RATIO) OF CORRECT TRIALS MADE IN THE TWO MAZE
SITUATIONS ON THE CONTROL SESSION

Subject	Two-turn task		Three-turn task	
	Large maze	Small maze	Large maze	Small maze
	% (and ratio) correct trials	% (and ratio) correct trials	% (and ratio) correct trials	% (and ratio) correct trials
1	68 (17/25)	23 (6/26)	-	-
2	63 (19/30)	82 (40/49)	-	-
3	83 (25/30)	43 (17/40)	-	-
4	75 (15/20)	92 (23/25)	85 (17/20)	63 (24/38)
5	67 (20/30)	11 (2/18)	-	-
8	-	-	75 (15/20)	3 (1/30)
11	-	-	80 (16/20)	73 (16/22)
12	-	-	71 (20/28)	7 (1/14)

TABLE 7
FREQUNCES OF EACH TYPE OF ERROR COMMITTED IN THE LARGE (THE
CUSTOMARY) AND THE SMALL (THE NEW) MAZE SITUATIONS ON THE
THREE-TURN TASK

Subject	Large maze			Small maze		
	One-turn error	Two-turn error	Four-turn error	One-turn error	Two-turn error	Four-turn error
4	0	2	1	0	13	1
8	2	2	1	15	5	0
11	1	3	0	1	5	0
12	1	6	1	6	7	0

This result suggests that disturbance may be due to the novelty of the new situation.

In this control test, the distance travelled in the small maze was drastically reduced (e.g., two turns in the large circular runway would be approximately equal to six turns in the small circular runway), yet at least two Ss in each task successfully transferred their performance without any further training. Thus, the results once again, do not support the view that successful performance was based on cues due to distance, and cumulative sensory feedback of running activities.

CONTROL TEST 3

METHOD

SUBJECTS

Rats 2, 3, 5, 8, and 12 were used for this control test.

APPARATUS

Figure 5 shows the ground plan of the maze used for this control test. It consists of two runways of different sizes and shapes, which not only share the same radial stem but also have a common runway section. The swing doors D1 and D2 can be simultaneously swung inward or outward, by the operation of lever L1 to alter the runway. When L1 is pushed inward D1 and D2 will simultaneously swing inward and a large maze will be formed. When L1 is pulled outward, D1 and D2 will move outward and the maze situation will be changed from the large to a small one. Thus in this control apparatus, the two runways can be interchanged, while S is in the common section of the apparatus, from turn to turn within a trial. Thus the present control test differs from the previous two, in which the lengths of the runways could not be varied within a single trial. The lengths of the runways are in a ratio of 3 to 2, i.e., going two turns round the large runway is equal to going three turns round the small runway.

PROCEDURE

Since this control apparatus was entirely new to Ss, the first step was to transfer Ss' performance to the large maze of this control apparatus. To facilitate this, some guidance was given. After S's performance had been successfully transferred, the control procedure was carried out in three successive stages:

- (1) S ran all the required number of turns in the large runway partly for warming-up, and

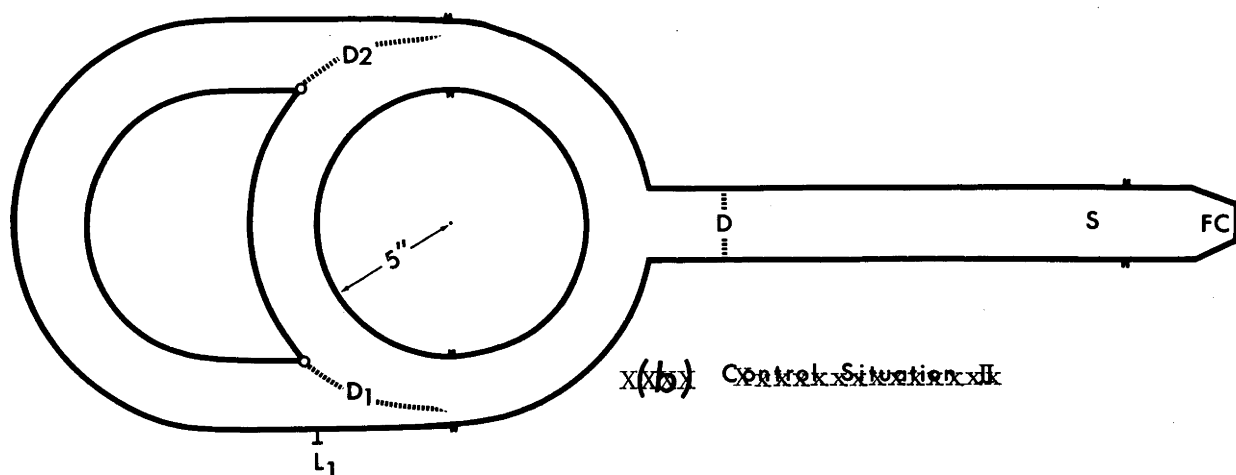


FIGURE 5

Ground plan of a control maze. D1 and D2 are swinging doors, which can be simultaneously swung inward by operation of lever L1 to alter the runways. The lengths of the runways are in a ratio of 3 to 2.

partly to make sure that it was performing correctly.

- (2) During this stage, the small runway was occasionally presented once in some trials to accustom S to the operation of the doors and the changes of the runways. If S still performed correctly despite this alternation, then the last stage (3) was introduced, otherwise the control procedure was discontinued, and a new session was started again from stage (1) on the next day.
- (3) The two runways were now randomly changed from turn to turn in each trial. Performance during this stage provide the crucial test.

The two runways were changed (i.e., lever L1 was operated) only when S was eating spaghetti at the food cup or at the moment it was about to pass the entrance and to start the next turn.

There were two exceptions to the above procedure. In stage (2) rats 3 and 12 ran all the required number of turns exclusively in one or other runway determined randomly. Secondly, for rat 3, stage (2) was extended to provide an alternative control measure and stage (3) was, therefore, unnecessary. This control test was carried out on the three-turn, the four-turn, and the five-turn tasks, and was tested only once for each S except for rat 12, which was tested six times on the four-turn task.

RESULTS AND DISCUSSION

Before the control test started, it had been expected that there would be many abortive control sessions, i.e., S would get disturbed on stage (2) and many sessions might be needed in order to overcome the disruption caused by the introduction of the new circular runway and the operation of the doors.

However, the results show that:

- (1) on the three-turn task, the numbers of abortive sessions were four for rat 2, one for rats 5 and 8, and nil for rat 3;
- (2) on the four-turn task, the number was two for rat 12;
- (3) on the five-turn task, it was nil for rat 12.

This quick habituation to the alternations of the runways might be due to the fact that they had experienced changing of maze situations on the previous control tests, and to the copious handling and taming they had received during the period of experimentation. At the very beginning of stage (2) the most commonly observed response of each S following the introduction of the new runway was to run into the stem after the completion of this turn in the new runway.

The performance of each S in stage (3) is shown in Table 8. The number of trials given in this stage depended upon S's performance. Each S was allowed to run as many trials as possible; generally the test stage was discontinued when the intertrial interval increased or S showed sign of restlessness, such as biting the floor of the maze, fiercely pushing the lids of the maze

TABLE 8
PERCENTAGE (AND RATIO) OF CORRECT TRIALS MADE IN STAGE (3) OF THE
CONTROL SESSION

Subject	Three-turn task	Four-turn task	Five-turn task
	% (and ratio) correct trials	% (and ratio) correct trials	% (and ratio) correct trials
2	78 (86/110)	-	-
3	86 (62/72)	-	-
5	83 (33/40)	-	-
8	88 (43/49)	-	-
12	-	52 (14/27)	80 (51/64)

etc., This is the main reason for the difference of the numbers of total trials among Ss.

It is evident from Table 8 that in this control test all the Ss were able to perform with considerable accuracy, even though the lengths and shapes of the runways were randomly changed from turn to turn or from trial to trial. The performance of rat 12 on the four-turn task, which had been tested for six times, was the least efficient of all, but its performance on the following five control tests was very efficient. The percentages (and ratios) of correct trials made in these five control tests ranged from 72 per cent (13/18) to 91 per cent (32/35) with a median at 82 per cent (50/61). The detailed characters and sequences of trials made in the control sessions are presented in Appendix IIa.

In this control situation, operation of the lever L1 was not likely to provide a cue for correct performance, because of the precaution taken to operate it only after S had commenced its run. There were also several correct runs when the last two turns had to be run in the same runway, so that no operation of L1 was necessary at the commencement of the last turn. Forty-nine such cases occurred in 86 correct runs by rat 2, for example.

Again, the results of this control test strongly suggest that successful performance was not dependent upon the length of the runway and the cumulative sensory feedback of running activities.

CONTROL TEST 4a

METHOD

SUBJECTS

The Ss used in this control test were rats 14, 15, 19, 20, and 21.

APPARATUS

Four temporal circular mazes were used in this control test. One of them was used as the standard training maze, the essential dimensions of which were: the radius of the inner wall of the circular runway, five inches, and the length of the radial stem, 20 inches. The radii of the inner walls of the circular runway of the other three mazes were 2.5 inches, five inches, (identical to the standard training maze), and 8.5 inches. A 20 inch radial stem was used for all three control mazes.

PROCEDURE

This control test was conducted on the three-turn task. It was carried out in a series of nine sessions. For example, in session 1, S was run in the standard maze, in sessions 2 and 3 it was run in the five inch control maze, and in session 4 it was again run in the standard maze; in sessions 5 and 6 it was run in the 8.5 inch control maze, in session 7 in the standard maze, and in sessions 8 and 9 in the 2.5 inch control maze. Sessions 2, 3 and 4, 5, 6 and 7, and 8 and 9 were run on consecutive days, while there was a fixed interval of rest for each S between sessions 1 (in standard maze) and 2 (in five inch control maze), between 4 (standard) and 5 (8.5 inch control), and between 7 (standard) and 8 (2.5 inch control) (see Table 9 for the resting interval for each S). It had been observed before the control test began that the imposed interval of rest did not affect the efficiency of Ss' performance. Since it was expected that transferring S to the new situation would cause some disruption of performance, extension of trials on each control session was allowed (see Table 9 for details).

RESULTS AND DISCUSSION

Table 9 shows the percentage (and ratio) of correct trials made by each S on three sessions that were run in the standard maze, and on the first session that was run in each of the three control mazes. The results on the second control session were generally better than those on the first (see Appendix IIb). It is apparent from Table 9 that rats 15, 19, and 20 were not disturbed when

TABLE 9

PERCENTAGES (AND RATIOS) OF CORRECT TRIALS MADE IN THE STANDARD AND THREE CONTROL MAZES

Maze situation	Subject				
	14	15	19	20	21
Standard	70 (21/30)	80 (24/30)	93 (28/30)	93 (28/30)	77 (23/30)
5 in. control: first 30 trials remaining trials	7 (2/30) 60 (37/62)	77 (23/30) -	87 (26/30) -	83 (25/30) -	13 (4/30) 83 (33/40)
Standard	93 (28/30)	83 (25/30)	97 (29/30)	80 (24/30)	87 (26/30)
8.5 in. control: first 30 trials remaining trials	20 (6/30) 55 (33/61)	30 (9/30) 90 (27/30)	10 (3/30) 83 (23/30)	67 (20/30) 80 (8/10)	33 (10/30) 77 (23/30)
Standard	83 (25/30)	73 (22/30)	77 (23/30)	63 (16/30)	77 (23/30)
2.5 in. control: first 30 trials remaining trials	47 (14/30) 95 (19/20)	0 (0/30) 0 (0/30)	47 (14/30) 66 (46/70)	63 (19/30) 87 (26/30)	77 (23/30) 85 (17/20)
Resting interval (in days)	2	4	8	4	2

transferred to the five inch control maze, which was identical to the standard maze. Rats 14 and 21 were disturbed at the beginning (judging from their scores on the first 30 trials), but they were able to perform quite efficiently afterwards. All Ss except rat 20 were disturbed at first when they were transferred to the 8.5 inch maze. However, without any guidance, their performance improved sharply after the initial period of disturbance, suggesting considerable transfer of performance. The results in the 2.5 inch maze show that except for rat 15, all Ss were able to perform fairly well in the first 30 trials, and performed very efficiently in the remaining trials. Although rat 15's performance was very poor in this maze, it should be noted that its performance was quite good in the 8.5 inch maze. Its performance in the following day was as bad (also see Appendix IIb) but it is interesting to note that when four guided trials were given immediately following the 60th free trial of this control session, it was able to make 23 correct out of the following 30 trials (77 per cent correct).

The performance of Ss in the 8.5 inch and 2.5 inch mazes, which differed from the standard maze in size, was viewed as a crucial test for the possible interpretation that S's correct performance was based on cues of distance and cumulative sensory feedback of running. Although the performance in these maze was somewhat disrupted at first, it was quite clear from subsequent efficient performance that the acquired habits could be retained in the mazes larger or smaller than the standard training maze. The early disturbance

was perhaps due to the novelty of the new situation, which cannot be fully controlled, and in the case of the 8.5 inch maze, the task would be harder because it would certainly take a longer time than in the standard maze to complete each turn. However, it should be noted that the initial disturbance can not be accounted for solely by the novelty of the external maze situation, since rats 15, 19, and 20 were able to perform very efficiently after being transferred to the five inch control maze, which was identical in dimensions to the standard maze but entirely new to them. Novelty of proprioceptive stimulation might also be involved.

The types of errors committed in the control mazes do not give support to the view that the distance cue was used for correct performance. They are mainly one-turn and two-turn errors (see Table 10). In the 8.5 inch control maze, the two-turn errors were what would be expected if the distance cue were the operative one, but it should be noted that on the three-turn task, the predominant type of errors was also the two-turn one, even in the standard training maze. In view of this and Ss' efficient performance in the 2.5 inch maze, it would seem that cues due to distance were not essential for successful performance.

TABLE 10

TYPES OF ERRORS MADE IN THE STANDARD AND THE THREE CONTROL MAZES

Maze Situation	Subject				
	14	15	19	20	21
Standard	E(2):9	E(2):6	E(2):2	E(2):2	E(1):2 E(2):5
5 in. control	E(1):11 E(2):41 E(4):1	E(1):2 E(2):5	E(1):3 E(2):1	E(1):3 E(2):4 E(4):1	E(1):11 E(2):22
Standard	E(2):2	E(2):5	E(2):1	E(2):6	E(2):3 E(2):1
8.5 in. control	E(1):3 E(2):48 E(4):1	E(1):7 E(2):17	E(1):14 E(2):18 E(4):1 E(5):1	E(1):1 E(2):11	E(1):3 E(2):24
Standard	E(1):1 E(2):2 E(4):2	E(1):2 E(2):5 E(4):1	E(1):3 E(2):4	E(1):1 E(2):10	E(1):3 E(2):4
2.5 in. control	E(1):4 E(2):12 E(4):1	E(1):28 E(2):32	E(1):11 E(2):29	E(1):3 E(2):12	E(2):14

CONTROL TEST 4b

METHOD

SUBJECTS

The Ss were 12 male white rats. Prior to this control test, they had been used for a detailed study of the effectiveness of various training schedules on learning of the two-turn task (see Chapter VII, Experiment 2 below), and for a study of the alcohol-tolerance effect (see Chapter IX, Experiment 2 below).

APPARATUS

The apparatus used comprised the five inch and the 2.5 inch mazes described in Control Test 4a.

PROCEDURE

The procedure of this control test was basically similar to that of Control Test 4a, except it involved only two sessions, i.e., on session 1, S was run in the five inch maze (the customary one), and on session 2, in the 2.5 inch maze (the control maze). The interval of rest between sessions 1 and 2 ranged from 2 to 3 days. On sessions 1 and 2, each S was run a total of 30 free trials, except for rats 28 and 32, which received some extra free trials on session 2. This control test was conducted on the two-turn task.

RESULTS AND DISCUSSION

Table 11 shows the percentages (and ratios) of correct trials made by each S on session 1 (in the customary maze) and on session 2 (in the control maze).

TABLE 11
 PERCENTAGES (AND RATIOS) OF CORRECT TRIALS MADE IN THE STANDARD
 TRAINING MAZE AND THE CONTROL MAZE

Subject	Percentage (and ratio) of correct trials		Resting interval (days)
	5 in. maze (standard)	2.5 in. maze (control)	
24	98 (28/30)	63 (19/30)	2
25	77 (23/30)	70 (21/30)	2
26	97 (29/30)	83 (25/30)	2
27	97 (29/30)	30 (9/30)	3
28	90 (27/30)	50 (15/30)	2
29	87 (26/30)	33 (10/30)	3
30	97 (29/30)	67 (20/30)	3
31	93 (28/30)	93 (28/30)	3
32	97 (29/30)	57 (17/30)	3
33	87 (26/30)	57 (17/30)	2
34	100 (30/30)	7 (2/30)	2
35	83 (25/30)	90 (27/30)	2

It is clear from this Table that most Ss were able to retain their acquired habits when transferred to the new smaller maze. Rats 27, 29, and 34 were disturbed by the new maze situation. Though the performance of rat 28 amounted to only 50 per cent correct, there was evidence that it was able to transfer its habit to the 2.5 inch maze. Its response sequence in the 2.5 inch maze was 15E(1) 15C, and when 20 further trials were run, it was able to make 19 correct out of these 20 free trials. Rat 32 was run five extra trials in the 2.5 inch maze after completion of the 30 trials, and all of these five trials were correct. The errors committed by all 12 Ss in the control maze were entirely one-turn errors, which gave no support to the view that distance or cumulative sensory feedback of running activities were the operative cues.

Again, following transfer to the new maze, the distance to be travelled had been drastically reduced (ratio 2 to 1), yet 9 out of 12 Ss were able to perform efficiently despite the change. This result gives further support to the view that the distance cue was not the essential factor for the correct performance.

TIME FACTOR

The other factor, mentioned also in the introduction of this chapter, that might be operating, was some type of time cue, i.e., S might just learn to 'go round the circular runway for a constant time'. In the aforementioned control tests, where the length of the circular runway was varied, time taken to complete the required number of turns would be varied when S was

transferred from one maze situation to another. Furthermore, observation of S's behaviour in the maze also suggests it is unlikely that S was just 'going round the runway for a constant time' before re-entering the stem (see also qualitative aspects of S's behaviour below).

In order to give more support to the above argument, the actual time taken by S to complete the specified number of turns was measured (timed from the moment the hind legs of S were about to clear the stem to the moment it ran into the stem again). Table 12 gives the results for all Ss that were timed. The results clearly show that the time taken by each S to complete a correct trial was not constant for all correct runs, even though there was no active control on the part of the Experimenter.

EXTEROCEPTIVE CUES

Since in this maze situation, S is confronted every time at the choice point with the same stimulus complex, it was virtually impossible that S would be aided by cues inside or outside the maze (olfactory cues from the reward were not present, since food was delivered on each correct trial only after S had made the decision). However, there were two exteroceptive cues that might provide the distinctive cues for the successful performance. Further efforts to control these two cues are described below.

TABLE 12
TIMES (IN SECONDS) TAKEN TO COMPLETE CORRECT TRIALS IN ONE
TRAINING SESSION

Subject	Task	No. of correct trials timed	Time (in seconds) taken	
			Mdn	Range
14	3-turn	24	8	6-12
15	3-turn	28	7	6-11
17	3-turn	28	7	6-15
22	3-turn	25	8	6-30
20	3-turn	26	7	6-10
12	4-turn	15	12	10-21
19	4-turn	30	8	6-13
19	5-turn	33	10	8-16

'CLEVER HANS' TYPE ERRORS

Since during the course of training, E had to be present to operate the sliding door for the guided trials, there was the possibility that E might inadvertently supply signals for S's differential responses, although the eyesight of Ss used is generally regarded as very poor. This type of error was controlled by letting S run the maze in the experimental room without the presence of any observer. Under this condition, no decrement in performance occurred. It is thus clear that the 'Clever Hans' type error was not involved.

POSSIBLE DISTINCTIVE CUES FROM THE CONTROL CIRCUITRY

The control circuitry, which was situated in the room next to the experimental one, would invariably produce some noise when it was activated. The noise to be considered here was from a stepper in the relay circuitry, which functioned partly as a temporary register of the numbers of turn made in each trial, and would make a sharp click every time a turn was made. Since the rotary switch of the stepper was always started from a fixed position at the beginning of each trial, there was an invariable connection between the noise of each successive click and the successive turn. Although the noises of successive clicks sounded no different to E, it was feared that S might be able to use them as a guide for its performance. This possibility was checked by turning off the circuitry on occasions; under this new condition no disturbance of performance occurred.

As in the control of the 'Clever Hans' type error, the results of this control test were so unequivocal that E did not bother to take down the results on the control sessions. However, there are two cases the results of which are available.

The first case is rat 14. This control was carried out on the six-turn task on the session following the criterion one. It has already been reported in the previous chapter that this S was able to reach the criterion of five consecutive correct trials without receiving any guided trial. On the following session, it was again able to perform so efficiently (23 correct

out of the first 27 trials) that E began to wonder if any other cues were available, i.e., from E and from the control circuitry. Thus the control circuitry was put out of action by turning off the light beams to the photocells in the maze at the end of the 27th trial, and E tried to hide away from S but in a position that enabled him to observe S's performance and count the number of turns it had made, so that he could operate the Spaghetti Gun when trials were correct ones. The performance of rat 14 on the following 20 trials was: 1C 1E(7) 1C 1E(7) 2C 1E(5) 2C 1E(5) 10C, 16 correct trials out of 20.

The second case is rat 20, and the control was also carried out on the six-turn task but on the criterion session. It had been reported in the previous chapter that this S was able to reach the criterion of five errorless runs so quickly (only after receiving six free trials) that E suspected some exteroceptive cues were employed for correct responses. The procedure for the control was similar to that applied to rat 14, and the result shows that rat 20 was able to make six correct out of ten trials when the circuitry was not functioning. Its response sequence was : 1E(4) 1E(5) 2C 1E(5) 4C 1E(5).

SOME QUALITATIVE ASPECTS OF S'S BEHAVIOUR IN THE MAZE BEHAVIOUR AT CHOICE POINT

There is a very prominent characteristic response at the choice point shown by all Ss on all tasks in both standard training and control mazes which is probably what other writers have called 'intention movement',

'mediational response' or 'vicarious trial and error'. On the completion of each turn (except the last one), S would come to a stop at the entrance of the stem, swing its head toward the stem or stand still for a moment, before starting the next turn. On the last turn, however, S would usually enter the stem without any delay. Although no objective evidence is available, it was apparent that S's running speed increased on the last turn.

CORRECTING RESPONSE

Sometimes Ss would enter the radial stem too early (usually on the penultimate turn), but instead of running straight down to the food cup, thereby committing an error, they would suddenly stop and return to the circular runway. They then either ran the whole sequence of a correct trial afterwards or made up the turn that they had almost missed. Since this is an incidental observation, being outside the main purpose of the experiment, precise quantitative data are not available. Rats 11, 12, 14, 15, 20 and 22 often displayed this behaviour. Occasional occurrence of this so called correcting behaviour was somewhat significant, because on most of the trials (no matter they were correct or erroneous), S would run straight down to the food cup without any delay and stopping.

SIDE PREFERENCE

Each S usually had its side preference, i.e., it was inclined to start its run in a clockwise or an anticlockwise direction, especially at an early stage of learning. However, there were some Ss in experiments

other than those of the previous chapter, which would go either way even at an early stage of learning. Even more interesting is that there were Ss that would start their runs in only one direction at the early stage of mastering and then would occasionally go the other way, and finally became bi-directional. One further comment seems proper at this point, although it was based on results of the following experiments. That is, the bi-directional Ss generally required larger number of trials to attain the criterion of five errorless runs.

DISCUSSION

In all control tests, change of the runway changed not only its length but also the curvature of its walls, and consequently would vary the sensory feedback of S's running activities and the time taken to complete a correct run. The results of these control tests strongly suggest that the successful performance was not dependent on the distance travelled, constant cumulative sensory feedback of running activities or a time factor. Incidental observation of S's behaviour in the maze also supports this view. Once stable performance had been reached, Ss showed that they were able to perform certain irrelevant actions in the course of running the maze (e.g., stopping to scratch or to groom) without interfering with correct execution. If the above cues were the crucial ones, it would be expected that Ss would run the maze in a more or less stereotyped manner, and these irrelevant actions would certainly affect their performance. Further efforts at controlling other exteroceptive cues show that neither the noise of the

operation of the automatic control circuit nor the experimenter himself supplied any distinctive cues to guide the animal's response.

The overall results of these control tests strongly suggest that the white rat can solve tasks which involve only a temporal sequence, without using information from exteroceptive cues, cues due to time, distance and cumulative sensory feedback of running activities. These results seem to force us to conclude that the behaviour of the white rat in the temporal circular maze meets the generally agreed criteria of 'ideational processes' in animals, e.g.,

Clear evidence for 'thought' in animals will be obtained in situations in which the relevant cues are not available in the external environment at the time the correct response is required, but must be supplied by the organism itself.

(Osgood, 1953, p.656)

More specifically, the behaviour meets the criteria of 'number' concept in animals:

There is considerable agreement amongst most investigators in the definition of a number concept. An animal is usually required to solve a problem without the aid of immediate physical variables. External cues such as size, shape, colour, brightness, tactile, odour, etc., as well as internal ones arising from rhythmic motor patterns or other visceral or kinesthetic feedback should either be absent or randomized from trial to trial, so that the numerosity of the stimulus constitutes the only constant variable.

(Wesley, 1961, p.420).

Koehler (1951) has put forward a hypothesis that man would never have started counting, i.e., naming number, without following two pre-linguistic faculties, namely, simultaneous and successive 'un-named number-sense'. These two faculties have been demonstrated by him and his co-workers in several species of birds (see summary by Thorpe, 1963), but so far only Wesley (1959) has taken pains to investigate these two faculties in rats, with very limited success. On the simultaneous discrimination task, some Ss were able to perform a 'two-ness task' but not a 'three-ness task'; on the successive task, some Ss learned to enter only a 'second' open alley without previously entering a first opening, which the author thought might only demonstrate the 'one-ness concept' (Wesley, 1961). In the present study, no attempt has been made to investigate the first faculty, namely the ability to compare groups of units presented simultaneously, for reasons already mentioned in Chapter II. As to the second ability, i.e., the ability to estimate number of incidents presented successively in time without being aided by other extraneous cues, the results of this study show for the first time that the white rat is able to approximate the achievement of birds (e.g., Lögler, 1959).

It is beyond dispute that the white rat, as well as the bird and other animals, is not 'counting' in the human sense. However, it is likely that the ability of the animal to learn tasks that seem to involve numbers only may represent a preliminary stage of counting, or may possess some fundamental elements of our counting behaviour.

No effort is made in the present study to demonstrate the existence of a completely abstract concept of number or true counting in the white rat, or to put it in Salman's way, to demonstrate that the white rat has the ability 'to recognise four blasts of a whistle, after training to four dots on a paper or four grains to be eaten' (1943, p.212). To achieve this end, development of other techniques is necessary, which would certainly require a great deal of time that this writer cannot afford at this stage.

Besides the problem of demonstrating true counting, there are other problems that are of equal interest and importance. They are to understand how learning in this maze takes place, and how the performance is affected by, for example, drugs. These problems are dealt with in the chapters that follow.

CHAPTER VI

GUIDED VERSUS TRIAL-AND-ERROR PROCEDURE

STUDIES ON THE EFFECT OF GUIDANCE ON LEARNING IN ANIMALS

The effect of guidance on learning is of theoretical and practical importance. However, this field seems to have not been extensively studied by comparative psychologists, and consequently little understanding has been achieved. The problem was first raised by Thorndike (1898) who concluded from his work on cats and dogs in problem box situations that the animals could not benefit from 'being put through' the act to be learned. The problem was later taken up by Cole (1907) working with racoons, and Hunter (1912) with rats in similar situations, and their findings showed that guidance was effective. The results of Cole's studies showed that the racoons could learn to undo fastenings by 'being put through'; time taken to learn by guidance was about half the time by trial-and-error, and even more significant, the animals could learn with guidance difficult problems that they could not master unaided. The main interest involved in these studies seems to hinge on the issue of, to put it in the current terminology, S-S or S-R learning. This same issue was later taken up by Gleitman (1955), and McNamara, Long, and Wike (1956) with rats in T-maze situations, in which guidance was carried out by pulling Ss through the maze on a trolley.

A more systematic study of this topic was carried out by Carr and his students. Carr and Koch (1919) working

with white rats, directly compared a guidance method and a trial-and-error method for effectiveness in establishing a series of single alternation responses. However, the experiment was inconclusive because Ss of both group failed to master the task with any high degree of proficiency, even after 2000-3000 trials. However, the trend of the results showed that Ss which were guided 40 out of every 50 trials did not master the task so effectively as did the unguided Ss. Koch (1923), using a complex spatial maze with nine blind alleys, continued the research with rats and human Ss. The general purpose of her experiment was to investigate the effect of the numbers of guided trials (2, 4, 6, 8, and 12), and the stages at which they were inserted (starting from the first, the third, the fourth, the fifth, the sixth, the seventh, the ninth, and the eleventh), on the learning of the problem. The guidance was carried out by closing the entrance to all blind alleys during the controlled (i.e. guided) trials; thus, according to the author, S was permitted "to initiate all his movements". In this respect, it differed from the method employed by Thorndike and Cole, in which Ss were passively guided by the experimenter through the movement of the act to be learned. Two general conclusions, which were then often cited as the doctrine on the effect of guidance on learning, were reached from her results: (i) the guidance was effective only when it was given in small amounts, and (ii) the effect of guidance was greater if given at the earlier stage of learning.

Using the same maze pattern as that of Koch, Tsai (1930) carried out an experiment to investigate the effect

of gradual and abrupt withdrawal of guidance on maze learning. In Koch's study, the procedure was to administer a certain number of guided trials at any desired stage of learning, and then discontinue the guidance abruptly, leaving the animal to learn the maze by itself until a certain criterion was reached. A so called gradual withdrawal procedure was used by Tsai, in which entrance to all blind alleys was at first prevented for a few trials, while on the next few trials some blind alleys were accessible. The number of blind alleys accessible was gradually increased until all of them were open. Amount of guidance was again studied (8 and 10 guided trials) under the abrupt withdrawal procedure, and the results showed that 8 and 10 guided trials exerted detrimental effects on learning in terms of the number of total trials and the error score. The conditions of gradual withdrawal were: (i) in the order of the distance of the blind alleys from the maze entrance, i.e., either from the first to the ninth or vice versa; (ii) from easy to difficult or vice versa; (iii) one or three alleys were opened on each successive trial. The results showed that: (i) the effect of gradual withdrawal of guidance was negligible (i.e., the guided groups required as many unguided trials as the unguided group to reach the criterion of learning), if withdrawal was on the basis of the distance of the blind alley from the entrance, except for the group whose guidance was withdrawn in backward order in group of three alleys, which showed a detrimental effect; (ii) it was detrimental when the guidance was withdrawn on the basis of difficulty. The effect of gradual withdrawal procedure as compared with the abrupt

procedure, was either similar or detrimental depending upon the modes of gradual withdrawal.

Alonzo (1926) working with white rats, investigated the effect of manual guidance on learning in a maze very similar to the Lashley III maze but with only four blind alleys instead of eight. The guidance was carried out by means of a leash attached to a collar, and S was allowed to run the maze on its own initiative. The leash was employed to prevent retracing and entrance to the blind alleys during the course of guided trials. As in Koch's study, the amount of guidance (2, 4, 6, 8, 12, 16, and 20 guided trials) and stages at which it was introduced (starting on the first, third and the fifth trial) were manipulated. The results showed that: (i) guidance exerted a detrimental effect upon six Ss, which refused to run the maze when guidance was withdrawn; (ii) guidance was detrimental in terms of the number of total trials required to learn the maze, i.e., the guided groups required a larger number of trials to master the maze than did the unguided group; (iii) with exception of one group, guidance was effective in terms of errors, time, and number of unguided trials required to learn the maze; (iv) the degree of individual variability was greater for guided groups, the indices of variability (mean variations/the corresponding means) tend to increase with the amount of guidance given; (v) the effectiveness of initial guidance increases with the amount of guidance, two guided trials exerted a detrimental effect upon learning while all larger amounts were beneficial; this contradicts the finding of Koch; (vi) the number of animals that succeeded in mastering the maze during the

period of guidance increased with the amount of guidance given, which suggests that errors are not essential to the mastery of the maze; (vii) four initially guided trials were less effective than the same number given between the third and the eighth trials; this again contradicts Koch's result.

Irrespective of the diverse and sometimes contradictory results of the above three experiments, which may be due in part to the differences of procedure and the apparatus used, some common conclusions can be drawn. In general, the trial-and-error method was more effective than the guidance method. If the effectiveness of guidance was assessed in terms of the number of the total trials (guided and free trials together) required to learn the maze, which seems to be the most proper index for comparison, the conclusions reached by Koch are applicable to all three experiments, that is, to be effective, the guided trials should be given in small amounts (no more than four guided trials); and when the amount increases, guidance has a detrimental effect on learning. The results of these studies have been interpreted by Carr (1930) as giving support to his view that the law of effect and the law of exercise are 'supplemental laws in that each is designed to explain a different feature of the learning processes' (p.207). The following quotation from the same review seems to be a good reflection of the theoretical purpose of these studies:

The occurrence of the erroneous responses thus exerts both a detrimental and a beneficial influence upon the speed of learning. Our results indicate that these erroneous responses

exert a detrimental effect when they occur in the earlier trials, but that their occurrence in the later trials is not only favourable but sometimes absolutely essential to the mastery of this type of skill. (p.200).

Bunch and Magdsick (1933) who were interested in the reminiscence phenomenon, introduced another interesting independent aspect of the effect of guidance on learning, namely, the time interval between the withdrawal of all guided trials and the onset of the trial-and-error learning procedure. Using a multiple T-water maze, they tried to determine the relationship between varying interval of time and the retention of an incompletely learned motor task in young white rats. Mechanical guidance (by blocking entrance to blind alleys) was employed to give seven groups of white rats comparable amounts of training (or so called 'incomplete learning') in the maze. The value of six guided trials when followed immediately by a mass practice until the maze was learned, was found to be slightly better than that of the unguided group, but statistically not significant, in terms of the number of unguided trials required to reach the criterion, and the error score. However, it is interesting that when an interval of 1, 3, 6, 12, 24, or 48 hours was allowed to elapse between these six guided trials and the subsequent mass practice, the guidance was found to reduce errors, time taken and the number of unguided trials required to learn the maze; the most favourable interval was one hour. The results were regarded by the authors as evidence of reminiscence in the white rat. Here again, if the effectiveness of guidance was assessed in terms of the total number of trials to criterion, it is possible that the effect of

guidance would be either detrimental or ineffective depending upon the conditions mentioned above. For example, under the 0 hour condition the average trials would be 20.12 against 16.60 for the unguided group, and for the one hour group the figure was 13.20.

A somewhat different question about the effect of guidance on learning was raised by Maier and his co-workers, who were interested in the effect of guidance on the alternation of an abnormal fixated position response caused, according to Maier, by the experience of frustration in an insoluble two-choice discrimination situation (Lashley jumping apparatus). Guidance was carried out by gently pushing S to the other side, whenever it was 'prepared' to jump to its fixated side. Following up an observation in their previous studies (Maier, Glaser, and Klee, 1940; Maier and Klee, 1943) that the fixated response may be broken by means of guidance, Maier and Klee (1945) compared directly the effectiveness of guidance versus trial-and-error procedures on the alternation of a position habit that was either acquired by differential reinforcement or formed in the insoluble situation. Subjects that had already formed adaptive or stereotyped position habits were required to learn a visual discrimination problem in the same apparatus under either trial-and-error or guided procedure. Thirty guided trials were given for the guided group at the onset of discrimination training. The results showed that: (i) 25 out of 28 Ss trained under guided procedure learned the discrimination while only nine out of 28 trained under trial-and-error procedure learned it; (ii) the function of guidance is

to break the old habit rather than to establish the new discrimination responses, i.e., the guidance hastens the abandonment of the old habits which was formed either through frustration or differential selection, but does not hasten the rate of learning the new habits. The same conclusions were reached in a second experiment, where the guidance groups received guidance on alternate trials throughout a total of 200 trials, i.e., 100 guided trials were given alternately with 100 trial-and-error trials, instead of 30 consecutive guided trials at the onset of the training. These findings led to a further study in which the number of guided trials was used as an index of the strength of fixation responses (Maier and Feldman, 1948).

In another study (Maier and Ellen, 1952), the prophylactic functions of the guidance were investigated. Subjects were at first trained either with or without guidance on a discrimination problem, and were then subjected to the frustrating situation of an insoluble task. Guidance was given on the last ten trials of every 50 trials. The whole of the experiment was carried out in four stages: (i) visual discrimination, (ii) insoluble problem, (iii) spatial or visual discrimination depending on Ss' performance in stage (ii), and (iv) Ss of guided group that did not fixate were given another insoluble problem to determine whether the guided trials given during stage (i) did entirely immunize them against fixating. The results showed that: (i) as in the previous investigation, the effect of guidance on the visual discrimination learning, i.e., in stage (i), was beneficial in the sense that it reduced the number of Ss that developed persistent position

responses (two out of 18 for the guided group against 16 out of 45 for the unguided group, which developed fixation); (ii) the guided trials did not help the Ss to adopt the discrimination response; (iii) at the end of stage (ii) nearly all Ss in both groups persisted in the previously acquired visual discrimination habit without shifting to position fixation; (iv) when a soluble problem was introduced again (spatial or visual discrimination), only one out of 16 Ss in the guided group failed to learn the new task while ten out of 28 unguided Ss failed to acquire the new habit. The authors concluded that guidance helps to prevent the formation of abnormal fixations.

THE PURPOSE OF THE PRESENT EXPERIMENT

It is clear from the above review that the purposes of those experiments were diverse. For Thorndike, Cole, and Hunter, guidance was used to study the mentality of animals, the existence of ideas, and their association; for Carr, it was used to investigate the functional value of errors in the learning process; and Maier was interested in its therapeutic effect on stereotyped abnormal responses which interfered with new learning. It is therefore not surprising that very little understanding of this problem has been achieved. Further investigations on this topic seem worthwhile.

The main purpose of this experiment is to compare the effectiveness of a guidance and a trial-and-error procedure on learning of the two-turn task in this temporal maze. It was also expected that the results of this experiment might provide some information about the

possibility of this maze being used for the more detailed study of the effect of guidance on learning. The techniques employed in those previous studies were not so effective in the sense that under those conditions the effect of guidance on learning, if not detrimental, was always too small to allow further experiments of parametric nature.

METHOD

SUBJECTS

The Ss used in this experiment were rats 1 to 10 inclusive of the Experiment 1 of Chapter IV.

APPARATUS

A temporal circular maze was used in this experiment. The radius of the inner wall of the circular runway was 8.5 inches and the length of the radial stem was 21 inches.

PROCEDURE

Although the general procedure of this experiment has already been mentioned in Chapter IV, a brief summary and some supplementary remarks on it seem to be desirable. As preliminary training, each S received five consecutive free trials daily for about 20 days with spaghetti delivered from the Spaghetti Gun at the end of each trial irrespective of S's performance. This preliminary training spread over a period of eight to ten weeks, because it was necessary to adjust some undesirable features of the apparatus that became

apparent during this period. However, every effort was made to equate the experience of all Ss during this preliminary training. The main purpose of this training was to make sure that each S would run the maze eagerly, and to reduce the retracing behaviour which occurred very frequently at an early stage of this training. The most frequently observed retracing behaviour was to return to the food cup just after emerging from the radial stem. After the preliminary training, Ss were randomly divided into two equal groups. Group I was trained with a guided procedure. For the first 11 days each S received five consecutive guided trials each day; from day 12, daily training was given according to the schedule: 3G 5F 2G 5F 2G 10F 3G, and at a later stage of training, extra trials were given, usually by successively repeating the 2G 10F pattern or by continuously giving free trials. Group II learned by the ordinary trial-and-error method; they received at first 20 free trials each day, but from the 14th session daily trials were increased to 50-70 to match the increased number of trials given to Group I.

RESULTS

At the time this experiment was discontinued, all five Ss in Group I reached the criterion of five consecutive correct runs while none of group II did, (see also Figure 6); the probability that this difference in distribution would occur by chance is .004 (Fisher exact probability test, Siegel, p.96). Table 13 presents the number of total trials, guided and free trials (errors and correct trials) required

TABLE 13

THE NUMBERS OF GUIDED TRIALS, FREE TRIALS (CORRECT AND ERRONEOUS TRIALS), AND TOTAL TRIALS REQUIRED BY SS OF THE GUIDANCE GROUP TO REACH THE CRITERION OF LEARNING, AND THE NUMBER OF TOTAL FREE TRIALS GIVEN TO THE UNGUIDED GROUP

Subject	No. of guided trials	Number of free trials			Number of total trials
		correct trials	one-turn errors	other types of errors	
1	90	15	68	nil	173
2	92	26	79	nil	197
3	119	63	139	E (3) : 2	323
4	132	33	170	E (3) : 3	338
5	137	28	181	nil	346
6	0	4	118	nil	122
7	0	38	643	E (3) : 1	682
8	0	27	601	E (3) : 3 E (4) : 1 E (5) : 1	633
9	0	34	644	E (3) : 1	679
10	0	3	86	E (4) : 1	90

to reach the criterion of learning for Group I (rats 1 to 5), and the number of trials (free trials) given to Ss of Group II (rats 6 to 10). Rats 6 and 10 refused to perform after receiving 90 and 122 trials respectively; they would usually sit at the food cup for a very long period on the last two or three sessions. Rats 6 and 7 were later randomly selected and then trained with a guidance procedure which differed from the one given to Ss of Group I in that they were given at first five consecutive

guided trials for six days instead of 11 days before being transferred to the training schedule mentioned in the procedure. Rat 6 required 131 total trials and rat 7, 325 trials to reach the same learning criterion. It is also very clear from Table 13 that for all Ss the errors made during the course of learning were predominantly one-turn errors.

DISCUSSION

It is apparent from the results that the trial-and-error method was quite ineffective in training the white rat to learn the two-turn task in this maze situation. It is clear from the learning curves of Figure 6 that the performance of Ss in Group II was so poor (actually declining) that it is doubtful that they would have eventually mastered the task, had the training been continued. It is likely that rats 7, 8, and 9 might have refused to run the maze in the same way as rats 6 and 10, had the trials continued. In this respect, this maze situation differs radically from those employed in the previous studies, where the rats were always able to master the problems by a trial-and-error method. This result (which is very similar to that of Cole's experiment with racoons which were able to learn acts that they failed to learn when unaided), is decisive evidence of the value of guidance for learning.

Guidance may have the effect of maintaining motivation since, without guidance, two Ss refused to continue the maze quite early. However, we should not neglect the other fact that there were still three Ss

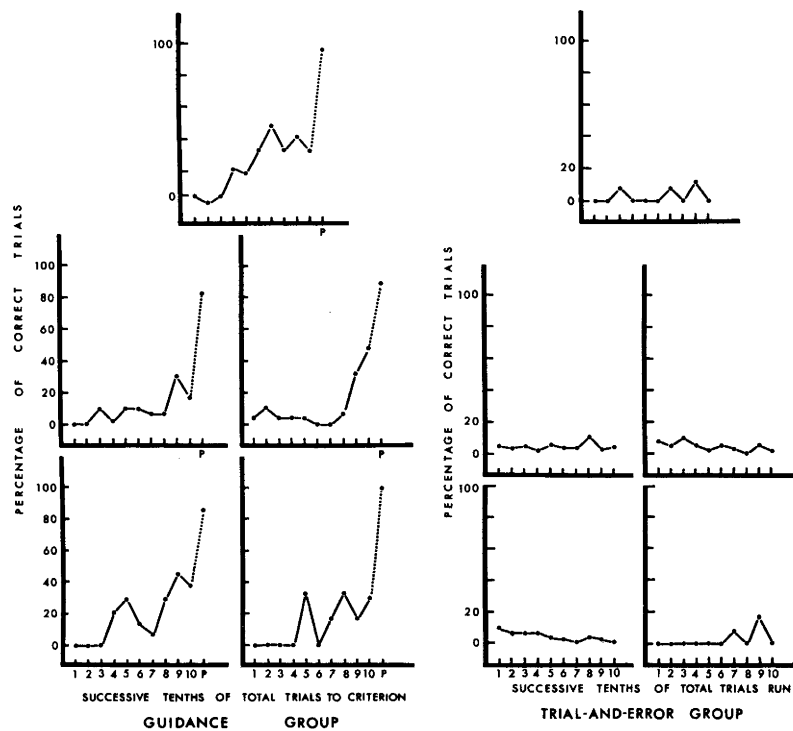


FIGURE 6

Showing the individual learning curves for Ss that were trained under guidance and trial-and-error procedures. A post-criterial point (P) was given for Ss of the guidance group, which shows the percentage of correct trials made in a block of post-criterion trials immediately following the fifth criterion trial, the number of which was equal to a tenth of the number of total trials to the criterion; e.g., if a S required 240 total trials to reach the criterion, (P) point shows the percentage of correct trials made in the 24 post-criterion trials that followed the fifth criterion trial.

vigorously continuing the maze for more than twice as many trials as Group I Ss, but without showing any sign of learning. This fact seems to suggest that guided trials might have effects other than just maintenance of motivation. Whether Maier's argument, that guidance serves only to break the old habit and thus make new learning possible, can be applied to this situation is certainly an interesting problem. There is a similarity between Maier's study and the present one. In Maier and Klee's study (1945) Ss were trained at first to form a position habit, before the new visual discrimination task was introduced. In the present experiment the preliminary training was in effect, to train Ss to form at first a one-turn habit (at the end of the preliminary training every S would invariably make one-turn trials). Thus in both situations Ss had at first learned one habit, and were then required to learn another which was incompatible with the old one. However, it is difficult in this experiment to separate, as clearly as in that of Maier and Klee's study, these two stages of learning, i.e., the breaking of the old one and the learning of the new one. This difficulty is fully reflected by the learning curves of rats 1 to 5 (see Figure 6), which clearly shows that the correct trials started quite abruptly. Furthermore, there is also the other possibility that Ss might actually learn the two-turn response directly without first breaking the old one-turn habit. The negligible incidences of overestimation errors (e.g., three-turn errors) committed by rats 1 to 5 during the entire course of learning seems to give some support to this speculation.

The amount of guidance given to each S in Group I was more than 4.5 times larger than the largest amount used by Carr's students (20 guided trials in Alonzo's study), but was about equal to that employed in Maier and Klee's study (1945) (100 guided trials were used on their second experiment). This result does not support the conclusion of Carr and his students' that, to be effective, guidance should be given in small amounts. Apparently the nature of the problems employed is a very important factor. The literature reviewed above also shows that when the number of total trials was used as the index for evaluating the effect of guidance, the guidance procedures were generally not so efficient as the ordinary trial-and-error method (sometimes even detrimental). There is argument as to whether the number of guided trials should be included in the learning scores. In this writer's opinion, they should be counted when effect of guidance is being evaluated. If a group of Ss have received a certain amount of guidance, say 50 guided trials, and still require as many free trials as (or even 20 trials less) those Ss trained under a trial-and-error procedure, it would seem absurd to conclude that the guidance procedure is as effective as (or more effective than) the trial-and-error method.

Examination of Table 13 also reveals that lack of learning by Ss in Group II can not be attributed to the fact that they did not make enough correct trials. The numbers of correct trials made by rats 7, 8, and 9 during the entire course of training were about the same as those made by rats 1, 2, 4, and 5. The curves in

Figure 6 show that they even occurred more frequently at the early stage of learning for Ss in Group II than for those of Group I.

On the whole, the results of this experiment show that when the white rat learns the two-turn task, the trial-and-error method is very ineffective, and some amount of guidance is necessary. Unlike most of the previous studies, in which guidance was found to be not so effective, or even detrimental, when the number of the total trials was used as the index for assessing the effect of guidance, the results of the present experiment show that guidance is highly beneficial. A fairly large amount of guidance is actually necessary which makes it possible to employ this maze technique to carry out studies of a parametric nature. This was not possible with the techniques used in the previous investigations.

CHAPTER VII

TRAINING SCHEDULES OF VARIOUS GUIDED/FREE TRIALS
(G/F) RATIO

It has been shown in the previous chapter that in order to train the white rat to learn a two-turn task, a certain amount of guidance is necessary. The results of that experiment also show that the amount of guidance given can be very large, which makes possible further experiments of a parametric nature. The typical procedure employed in previous studies was to introduce a certain amount of guidance at some stage of learning, and then discontinue it, leaving the animals to learn by trial-and-error until the criterion was reached. The interest was to study the effect of the number of the guided trials and the stage at which they were introduced. There is no study that manipulates certain combinations of the number of guided and free trials (i.e., training schedules), treats these combinations as units and investigates the effect of these units on learning. This problem is worth studying because it is more like the human teaching situation, in which the sequence of guidance and free trials may be repeated for several times until learning occurs. Furthermore, studies of this kind may also provide some understanding of the combined effect of the guided and free trials on learning, and on the possible application of this maze in the fields of comparative and physiological studies. It seems to this writer that the most fundamental problem at this stage of the present study is to

determine first the most effective schedule (or schedules) to train the white rat to learn the two-turn task.

EXPERIMENT 1

The main purpose of the present experiment was to compare for effectiveness three training schedules: 4 x (3G 3F) ($G/F=1$), 3 x (3G 6F) ($G/F=1/2$), and 2 x (3G 9F) ($G/F=1/3$).

METHOD

SUBJECTS

Thirty white rats aged about 15 weeks at the beginning of the experimental training were used. They were housed in groups of five with water freely available and were maintained on a 22-24 hours food deprivation schedule.

APPARATUS

The radius of the inner wall of the circular runway of the maze used in this experiment was five inches and the length of the radial stem was 20 inches.

PROCEDURE

The preliminary training was carried out in the temporal circular maze. On day 1, each S was allowed to explore the maze freely for five minutes; from day 2, each was given one free trial a day for nine days and spaghetti was always delivered at the end of that trial irrespective of its performance. From day 8 to

day 10, two additional pieces of spaghetti were given to some timid Ss to make sure that they would not be frightened by the noise of the operation of the Spaghetti Gun. After preliminary training all Ss were randomly divided into three equal groups. Group I was trained under the schedule of 4 x (3G 3F), constituting 24 trials each session. Group II was trained under the schedule of 3 x (3G 6F) totalling 27 trials each session, and Group III under 2 x (3G 9F) totalling 24 trials each session. Guidance was discontinued when S reached the criterion of five consecutive correct runs. On the criterion session, Ss were allowed to complete their assigned daily trials irrespective of when the criterion was reached. Training was discontinued for each S only when it had made at least 10 consecutive errorless runs. The number of trials (free trials) given to each S on the post-criterion training sessions was similar to that given in the pre-criterion ones.

Because of the limited time available for this experiment, each group was further randomly divided into two halves, and the sub-groups were then trained on alternate days. At the beginning of the experimental training, a time limit of 25 minutes for each session was found to be necessary, which was very possibly due to the limited amount of preliminary training given to each S. All but five of the Ss were able to complete the assigned numbers of trials within this time limit after two to five training sessions in the maze.

RESULTS AND DISCUSSION

By the time all ten Ss in Group I had reached the criterion of five consecutive correct runs, only six in Group II and three in Group III had reached the same criterion. The experimental data are given in Table 14. Since the scores to criterion are not available for all Ss in Groups II and III, the upper scores of the ranges shown are the largest scores available in each group, and the median for Group III can only be inferred as larger than the scores shown in the Table. The results clearly show that the 4 x (3G 3F) (G/F=1) schedule is overwhelmingly better than the other two schedules.

Applications of the median test (Siegel, 1956, p.179) to the results show that:

- (1) At the time the experimental training was discontinued, the numbers of guided trials given to each group did not differ significantly ($X^2=2.4$, $df=2$, $p>.25$).
- (2) The number of free trials experienced by Ss of each group differed significantly ($X^2=15.2$, $df=2$, $p<.001$). Fisher tests showed that the score of Group I is significantly smaller than Groups II and III ($p<.05$). A further analysis showed that the majority of these free trials were erroneous trials (predominantly one-turn errors; errors of other types can be neglected), the numbers of which also differed significantly among groups ($X^2=15.2$, $df=2$, $p<.001$). Again, Fisher tests showed that the score for Group I is smaller

TABLE 14

COMPARISON FOR THE EFFECTIVENESS OF THE THREE TRAINING SCHEDULES, 4 x (3G 3F), 3 x (3G 6F), AND 2 x (3G 9F), ON ACQUISITION OF THE TWO-TURN TASK

Training schedules	No. of guided trials to criterion		No. of free trials to criterion			
	Mdn	Range	No. of correct trials		No. of errors	
	Mdn	Range	Mdn	Range	Mdn	Range
4 x (3G 3F)	224.5	120-376 ^a	45.5 ^b	30-56	184.5	87-336
3 x (3G 6F)	228.5	118-333 ^a	59.5 ^b	43-69	395.5	181-630 ^a
2 x (3G 9F)	larger than 228	64-228 ^a	35 ^b	30-55	larger than 627	174-627 ^a
					231	121-381
					455	227-666 ^a
					larger than 659	174-659

Training schedules	No. of total trials to criterion		Total time to criterion (in minutes)		Average time per session (in minutes)	
	Mdn	Range	Mdn	Range	Mdn	Range
4 x (3G 3F)	449.5	241-757	242	170-477 ^a	12.1	11.3-17.7 ^a
3 x (3G 6F)	677	345-999 ^a	347	221-864	15.9	11.5-23.4 ^a
2 x (3G 9F)	larger than 873	238-873 ^a	larger than 395	202-850 ^a	16.8	15.2-25 ^a

a. the upper limit shown is the largest score of Ss that failed to reach the criterion.

b. based on successful Ss only.

than those of Groups II and III ($p < .01$). Since the numbers of correct trials for Groups II and III can not be properly inferred, these results will not be considered. However, the available data seem to suggest that they will not differ significantly among themselves.

- (3) The medians of the numbers of total trials required to reach the criterion were found to differ significantly at the .01 level ($X^2 = 9.6$, $df = 2$). Fisher tests showed that the median score of Group I did not differ from that of Group II ($p > .05$), but differed significantly from that of Group III ($p < .05$).
- (4) When the effectiveness of the training schedules is evaluated in terms of total time to reach the criterion of learning, the results shows that there is a significant difference among groups ($X^2 = 7.2$, $df = 2$, $p < .05$), and that Ss of Group I took significantly less time than did Ss of Group III to reach the criterion of learning ($p < .05$, Fisher test); Groups I and II did not differ significantly from each other ($p > .05$, Fisher test).
- (5) The result on the average time taken per session shows that there is a significant difference among groups ($X^2 = 12.8$, $df = 2$, $p < .01$), and Fisher tests show that Ss of Group I took less time to complete their daily session than Ss of Groups II and III ($p < .05$, and $p < .01$, respectively). However,

it should be noted that the number of daily trials assigned to Group II was 27, while for Group I it was 24.

It is clear from the above results that the 4 x (3G 3F) schedule is the most effective one among those tested, and the effectiveness of the training schedules seems to be in direct proportion to the number of guided trials given on each session. The results also suggest that those extra errors made by Ss of Groups II and III interfered with learning. They increased time taken to complete each daily session, and also seemed to counteract, for the majority of Ss, the beneficial effect of guidance.

In this experiment, it was unfortunate that at the very beginning of the experimental training most Ss could not complete their assigned daily trials in 25 minutes. One S in Group III actually did not overcome this difficulty during the entire course of training, and the other S in Group II could not finish the assigned trials within the time limit for the first 24 training sessions. This undesirable phenomenon may be due partly to the short period and small amount of the preliminary training given to each S. Thus at the beginning of experimental training a lot of retracing behaviour occurred between trials, most of which was retracing back to the food cup as soon as S ran out of the radial stem. This result has a practical implication. In order to make the experiment less time consuming especially at the beginning of the experimental training, it may be desirable to give as much preliminary training as possible.

EXPERIMENT 2

It has been shown above that a training schedule with G/F ratio of one was more effective in training the white rat to learn the two-turn task than schedules where this ratio was smaller than one. The main purpose of the present experiment was to compare, for the same task, the effectiveness of a training schedule with a G/F ratio of two with two different schedules where the G/F ratio is one. Thus a 3 x (4G 2F) (G/F=2), a 3 x (4G 4F) (G/F=1), and a 3 x (2G 2F) (G/F=1) schedule were employed. These schedules were so elected that the number of guided trials given on each training session was constant for the schedules 3 x (4G 2F) and 3 X (4G 4F), and the number of free trials given to the schedules 3 x (4G 2F) and 3 x (2G 2F) was constant. In the present experiment, the effectiveness of training schedules was assessed in two ways instead of only one as in Experiment 1: (i) relative rate of approaching a predetermined criterion of learning, and (ii) the efficiency of the post-criterion performance.

METHOD

SUBJECTS

The Ss were 24 male white rats about 18 weeks old at the beginning of the experimental training. They were housed in groups of eight with water freely available, and were given an average amount of 8 gm per S (64 gm for each group) of dry laboratory rat food soon after all Ss in each group had completed their daily training.

APPARATUS

As in Experiment 1.

PROCEDURE

Preliminary training. Feeding familiarization. In this experiment, a 4 x 4 x 19 inch box with a food cup at one end, identical to the one in the temporal circular maze, was employed for feeding training to habituate S to the noise of the operation of the Spaghetti Gun (SG). On each day, S was placed in the feeding box and allowed to stay there until five pieces of spaghetti were consumed. On the first six days two pieces of spaghetti were put into the food cup before S was introduced into the box, and the remaining three were delivered through SG; on the following two days all five pieces were delivered through SG. Three extra pieces of spaghetti were given to Ss that were relatively timid on the last two days. The SG was operated manually only when S's head was over the food cup. At the end of the feeding training, every S would eagerly look for the spaghetti at the onset of the operation of SG without any sign of being frightened by the noise of SG.

Maze familiarization. After feeding training all Ss were transferred to the temporal circular maze and were run five trials each day for nine days to familiarize them with the maze and to reduce the undesirable retracing behaviour. Spaghetti was given from SG at the end of each trial irrespective of S's performance.

Experimental training. Pre-criterion training. After preliminary training Ss were randomly divided into three equal groups. Group I was trained under the 3 x (4G 2F) schedule, Group II under 3 x (4G 4F), and Group III under 3 x (2G 2F). However, during the course of training minor variations from the schedules were made. In particular: (i) when the last free trial of each block was a correct one, an extra free trial (or trials as the case might be) was given, and (ii) if S made two or more (but less than five) consecutive correct runs further free trials were run until two consecutive errors occurred. The criterion of learning was five consecutive correct runs, and guidance was discontinued when the criterion was reached.

Post-criterion training. On the criterion session, 20 extra free trials were run immediately following the fifth criterion trial. On following sessions, each S was run on a daily session of 30 free trials, and sessions were continued until a certain level of stable performance was reached. Stability of performance was said to have been attained: (i) when S made at least 80 per cent correct (i.e., at least 24 correct trials) on each session for five consecutive sessions, and (ii) the range of the number of correct trials on these five consecutive sessions was not larger than four. These criteria of stable performance had been determined before the experiment started.

RESULTS AND DISCUSSION

ACQUISITION

Table 15 presents the experimental data on acquisition for the three groups. The overall comparison of groups was tested, throughout this experiment, by the Kruskal-Wallis one-way analysis of variance by ranks (Siegel, 1956, p.184). Statistical analysis showed that there were no significant differences among groups in terms of the number of total trials to criterion ($H=2.34$, $df=2$, $p>.30$), and in terms of total time to the criterion ($H=3.42$, $df=2$, $p>.20$), although the 3 x (4G 2F) schedule seems to be slightly better than the other two. It is apparent that the range of scores of Group I was greater than those of the other two groups. For example, a Bartlett test indicated significant heterogeneity of variance among groups in the total-trial-to-criterion score ($B=7.16$, $df=2$, $p<.05$). The variances were 26123.13, 4476.30, and 4202.70 for Groups I, II and III respectively; F-tests indicated that the variance of Group I was significantly larger than that of either Group II ($F=5.84$, $df=7/7$, $p<.05$) or Group III ($F=6.22$, $df=7/7$, $p<.05$). It is interesting to note that the variances of Groups II and III, which were trained under a schedule with $G/F=1$, did not differ significantly ($F=1.07$, $df=7/7$, $p>.10$). Further experiments with large samples are necessary for a final conclusion on this interesting feature.

Since there were built-in differences in the proportion of guided and free trials among these three training schedules, it seems worth while to examine

TABLE 15

COMPARISON FOR THE EFFECTIVENESS OF THE THREE TRAINING SCHEDULES,
3 x (4G 2F), 3 x (4G 4F), and 3 x (2G 2F), ON ACQUISITION OF THE TWO-TURN TASK

Training Schedules	No. of guided trials to criterion		No. of free trials to criterion						No. of total trials to criterion		Total time to criterion (in minutes)		Average time per session (in minutes)	
			No. of correct trials		No. of errors		No. of total free trials							
	Mdn	Range							Mdn	Range	Mdn	Range	Mdn	Range
	3x(4G 2F)	178	132-408	13	5-34	88	67-213	112	74-234	290	209-642	112	82-250	7.1
3x(4G 4F)	168	160-240	27	11-40	158	138-227	173	167-257	341	327-497	153.5	142-194	10.8	7.8-12.1
3x(2G 2F)	147	117-216	28	12-42	150	113-197	180.5	125-225	327	242-441	155.5	104-259	6.1	4.3-8.4

whether there are any differences among groups in terms of the number of guided trials and the number of free trials (erroneous and correct trials). Statistical analyses indicated that there was no significant difference among groups on the guided-trial score ($H=4.9$, $df=2$, $p<.10$), on the free-trial score ($H=4.9$, $df=2$, $p<.10$), and on the error score ($H=5.65$, $df=2$, $p<.10$). However, it is interesting that there was significant difference among groups in the number of correct trials made during the course of training ($H=6.03$, $df=2$, $p<.05$). The Mann-Whitney U tests (Siegel, 1956, p.116) showed that the numbers of correct trials made by Ss of Group I were significantly less than those of Groups II and III ($U=13$, $p=.05$, and $U=12$, $p=.038$, respectively). However, this result might be due to the fact that the proportion of free trials was smaller for Group I than for Groups II and III, thus Ss of Group I had less chance to accumulate correct trials. The incidence of these correct trials during the course of training for each individual S is shown in Figures 7(a) and 7(b), which again show the trend of positive acceleration.

Comparison among the groups in terms of the average time taken per session were not feasible because the number of trials in each session differed amongst the groups. There was no significant relation between the speed of completing a session (average time per session) and speed of reaching the criterion (number of total trials to criterion) (rank correlation coefficients were -0.05 , 0.02 , and 0.07 for Groups I, II and III respectively).

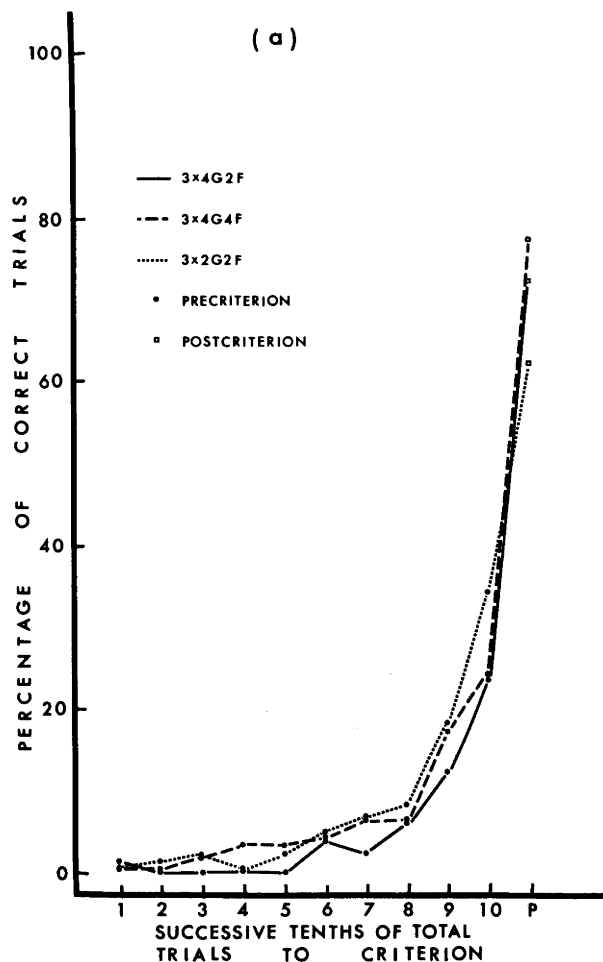
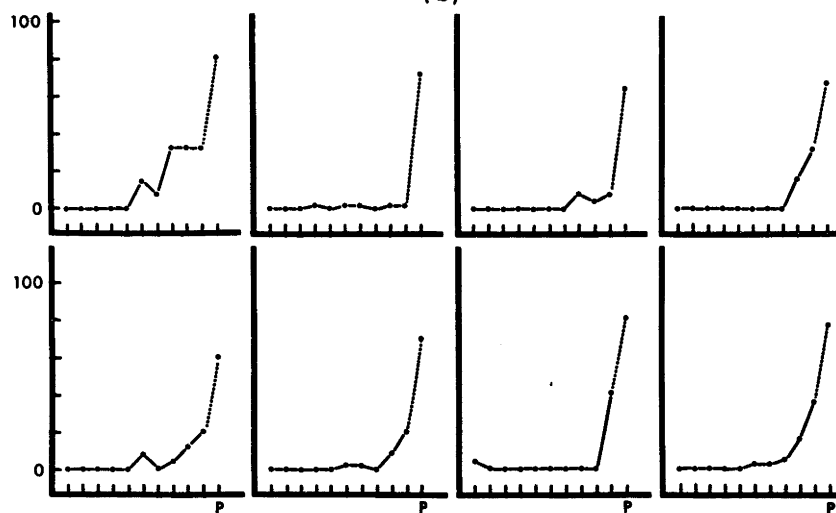


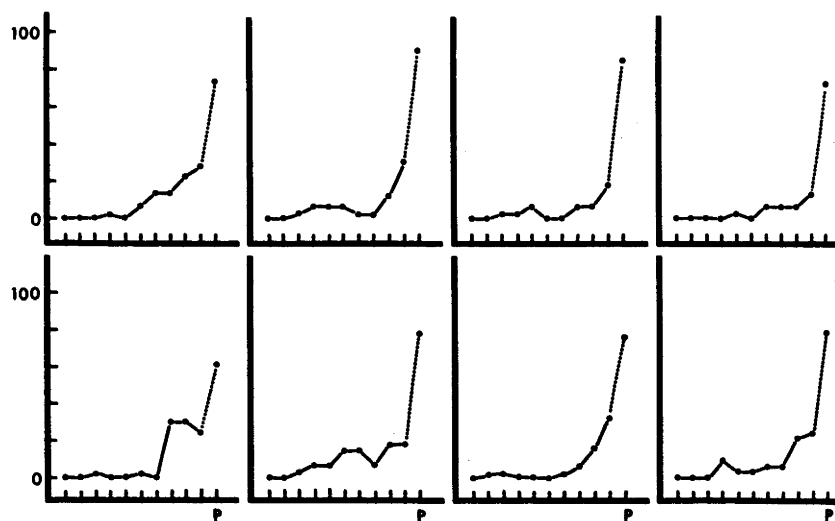
FIGURE 7

(a) Average learning curves for the three groups trained under the 3 x (4G 2F), 3 x (4G 4F), and 3 x (2G 2F) schedules, and (b) individual learning curves for 24 Ss of these three groups (next page). Note the trend of extreme positive acceleration in the group as well as the individual curves, which suggest sudden learning. A post-criterial point (P) was provided for each curve, which shows the percentage of correct trials made in a block of post-criterion trials immediately following the fifth criterion trial, the number of which was equal to the tenth of the number of total trials to the criterion, e.g., if a S required 240 total trial to reach the criterion, then the number of the block of the post-criterion trials was 24. The post-criterion points of group curves were the average scores.

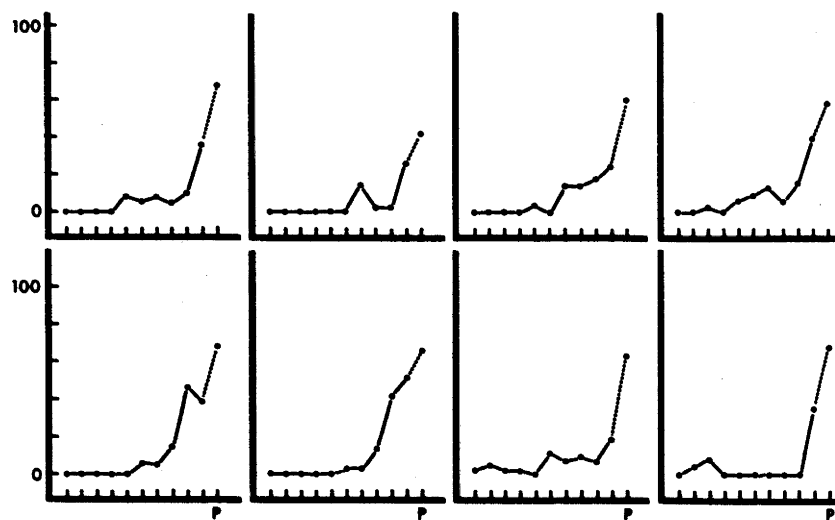
(b)



3 X 4 G 2 F



3 X 4 G 4 F



3 X 2 G 2 F

POST-CRITERION PERFORMANCE

Comparisons were made in terms of the following measures (the first two were decided before the experiment started, while the last one was chosen post hoc): (i) number of correct trials made by each S in the first 50 post-criterion trials, i.e., those 20 free trials following the fifth criterion trial together with those 30 trials of the first post-criterion session, (ii) number of post-criterion sessions required by each S to reach the stable performance level specified in the procedure, and (iii) the range of the number of correct trials made on the first ten post-criterion sessions (the number of ten sessions was decided before the statistical analysis started). Table 16 presents the data in the post-criterion performance. Statistical analysis showed that:

- (1) The effect over the groups in terms of the number of correct trials made in the first 50 post-criterion trials was significant ($H=10.12$, $df=2$, $p<.01$). The Mann-Whitney U tests showed that Groups I and II did not differ significantly from each other, but they were significantly better than Group III ($U=7$, $p=.006$, and $U=6$, $p=.004$ respectively). This result seems to suggest that the level of performance soon after the criterion was better for Ss that were trained under schedules that included larger number of guided trials.
- (2) The effect over the groups in terms of the number of post-criterion sessions required to

TABLE 16
COMPARISON OF THE EFFICIENCY OF THE POST-CRITERION PERFORMANCE FOR
THREE GROUPS TRAINED UNDER THE 3 x (4G 2F), 3 x (4G 4F), AND
3 x (2G 2F) SCHEDULES

Training schedules	No. of correct trials in first 50 trials		No. of sessions to stability criteria		Range of the No. of correct trials on first 10 sessions	
	Mdn	Range	Mdn	Range	Mdn	Range
3 x (4G 2F)	38.5	33-44	0	0-8	4	4-13
3 x (4G 4F)	39.5	34-47	1.5	0-10	7	5-14
3 x (2G 2F)	33	28-38	3	1-7	8.5	7-13

attain the stability criteria was not significant ($H=5.64$, $df=2$, $p<.10$). However, it is worth noting that the 3 x (4G 2F) schedule was significantly more effective than the 3 x (2G 2F) schedule ($U=9$, $p=.014$), even though the analysis of variance failed to show significance.

- (3) The overall effect on the range of the numbers of correct trials made on the first ten post-criterion sessions was significant ($H=8.98$, $df=2$, $p<.02$). The Mann-Whitney tests showed that Group I was significantly better than Groups II and III ($U=12$, $p=.038$, and $U=8$, $p=.01$ respectively). This result seems to suggest that the performance of Ss trained under the schedules with $G/F=1$ was less stable than those Ss trained under the schedule with

$G/F=2$. Or in other words, the performance of Ss that were trained under schedules that included more free trials (consequently made more errors) was less stable than that of Ss that experienced less free trials. The trend of the result on the stability criteria (see (2) above) was also in this same direction.

The above results were viewed as giving some support to a working hypothesis that the effectiveness of training schedules cannot be accounted for entirely in terms of the number of guided or free trials alone, but rather it is the interaction of the two which is important. If the number of guided trials alone were important, then no differences would be expected between Groups I and II, which received equal numbers of guided trials each day. On the other hand, if the free trials alone were essential then there should be no differences between Groups I and III, which received equal numbers of free trials each day.

The results of this experiment also suggest that the performance of the white rat in this maze situation on the two-turn task can be very stable. This conclusion is supported by the fact that all 24 Ss were able to reach the nominated stability criteria, namely, to make at least 80 per cent correct trials for five consecutive sessions, with the range of the number of correct trials on these five sessions not larger than four. This feature meets one of the basic requirements for a behavioural technique to be used in drug studies.

THE EFFECT OF EXTENSIVE PRELIMINARY TRAINING

In this experiment, ample preliminary training was given to each S before the experimental training started. The beneficial effect of this preliminary training at the early stage of the experimental training was fully reflected in the following results. On the first training session, only two Ss out of 24 required more than 25 minutes to complete their assigned daily trials (the median time was 12.5 minutes, and the range: 7-30 minutes), and on the second session none of them failed to complete their daily trials within this time limit (median: 8.5 minutes, and range: 5-16 minutes), which was significantly better than the results of Experiment 1. For example, on the first training session, all ten Ss of Group I, which were trained under 4 x (3G 3F) schedules could not complete their daily trials within 25 minutes (the total numbers of trials made in this session ranged from 6 to 20 with a median at 7), and on the second session only three Ss were able to complete the assigned trials in 25 minutes. (The results of Groups II and III were worse than those of Group I). Since there is no decisive evidence that this extensive training did affect the subsequent learning, it seems proper to conclude that, for practical purposes, more extensive preliminary training is desirable.

DISCUSSION

From the results of these two experiments, a tentative conclusion can be drawn. That is the effectiveness of training schedules in training the white rat to learn the two-turn task seems to be in

direct proportion with their G/F ratios. The results of Experiment 1 clearly show that the most effective training schedule was the one with $G/F=1$. While the results of Experiment 2 were not so clear cut as those of Experiment 1, they seem to be in the same direction, i.e., the schedule with $G/F=2$ was generally more effective than the other two, the ratio of which was one.

Besides its putative value to the understanding of human learning, there are at least two other reasons for the study of the effectiveness of training schedules. Firstly, since the temporal circular maze possess some advantageous features for behavioural drug studies (see Chapter IX), it is of practical importance to find out the most efficient ways of training the white rat to learn the two-turn task, and to determine exactly the effect of each training schedule on learning. Secondly, it is the interest of this writer to see if any functional relations can be established in this maze situation for the rat, e.g., if there is any orderly relationship between the effectiveness of training schedules and the G/F ratios. Investigations of this kind would provide a great deal of knowledge on some aspects of behavioural shaping, and would also have some implications for this maze being used in the phylogenetic comparison of animals' learning capacities.

There are two possible ways of using the temporal circular maze for phylogenetic comparisons. The first method is to determine, for each species of animal, its capacity limit in this maze situation. Studies of this type always involve three general difficulties, namely,

the equating of sensory, motor, and motivational factors, among the species of animals studied. Although it has been pointed out in Chapter IV that in this maze situation no special exteroceptive sensory processes, e.g., visual, and motor skill, dexterity, e.g., is crucial for the successful performance, the problem regarding equating motivation among species studied still exists. A second method, which may overcome this difficulty, is in principal similar to the one advocated by Bitterman (1960); this is to determine whether the same functional relation is operating in various species of animals. For example, if it could be established that, within a reasonable range in which the number of guided and free trials were manipulated, for the white rat the most effective training schedule (or schedules) was the one with $G/F=2$, then it would be interesting to know if this functional law was operative in other species of animals such as cats, dogs, etc., as well; if not, what were the optimal training schedules for them, and how do the optimal schedules of different species differ. It is apparent that the feasibility of this method depends greatly upon whether any functional laws about training schedules can be established first in the white rat. In this respect, the findings in Experiment 2 that there were similarities in the effect of the 3 x (4G 4F) and the 3 X (2G 2F) schedules (both with $G/F=1$) on learning the two-turn task is quite an encouragement.

There is another methodological problem, i.e., whether the arbitrary criterion of learning, namely, five consecutive correct runs, is a proper one or not. Rank correlation coefficients between the numbers of

total trials to reach this criterion and the numbers of total trials to reach ten errorless runs, were obtained from 19 Ss of Experiment 1 that had learned the task and from 24 Ss of Experiment 2. They are 0.99 and 0.93 respectively, which are significant at 0.01 level. It thus appears that the criterion of five errorless runs used is quite proper.

CHAPTER VIII

TRAINING SCHEDULES WITH G/F RATIO OF ONE

It has been suggested in the previous chapter that the effectiveness of a training schedule can not be accounted for entirely in terms of either the numbers of guided or free trials alone, but rather the combination of the two. This implies that the effectiveness of various training schedules with equal numbers of guided and free trials may differ from each other when these two types of trials occur in different combinations. The only method available to investigate this problem is to compare the relative effectiveness of training schedules of the same G/F ratio. The main purpose of the following two experiments was to compare the effectiveness of various training schedules with G/F ratio equal to one on learning the two-turn task. It is apparent that results of these experiments will throw some light on the understanding of the relative effects of the length of the runs of guided and free trials on learning; i.e., if the same numbers of guided and free trials are to be given which is more effective, when they are administered in long runs or in several more repetitions of short runs? For example, if eight guided and eight free trials are to be administered, which of the following ways will be more effective, (8G 8F), 2 x (4G 4F), or 4 x (2G 2F)?

EXPERIMENT 1

The primary purpose of this experiment was to compare the training schedules: 4 x (3G 3F), and 2 x (6G 6F) (both with $G/F=1$) for effectiveness in teaching the white rat to learn the two-turn task. A secondary purpose was to find out if there were any age differences in the ability of the white rat to learn this same task. Early experiments on this topic showed that there were no significant age differences in learning ability of the rat, except at the age levels younger than 30 days (see Munn, 1950, e.g.). Further, extensive studies by Stone (1929, a and b) on the age factor in learning have shown that the maximum learning ability for mazes, problem boxes and discrimination problem is reached at 30-70 days, and that motivation is one of the most confounding factors in this type of study. There were, nevertheless, reasons for a pilot study on this problem using this temporal maze technique:

- (1) Maier (1932) using a reasoning test, in which Ss were required to combine two isolated experiences to obtain rewards, found that the performance of young rats (50-90 days) is inferior to that of the older ones (120-300 days).
- (2) Vince (1961), on the basis of her experiments on birds, suggests that there are two behavioural processes, namely, internal inhibition and responsiveness, which develop differentially at different ages, and that the internal inhibition develops more slowly and responsiveness reaches its peak at an earlier age level. Thus there are age differences in

learning ability, which depend upon the nature of the task to be learned. In tasks depending upon the level of activity the young one will be superior, while the older one will be superior on the task that demands a certain amount of restraint.

Since it is assumed that, in order to learn the two-turn task in this maze situation, some type of inhibition is required, i.e., to refrain from running into the stem at the end of the first turn, it is thus interesting to see if any age differences can be obtained in learning the two-turn task.

METHOD

SUBJECTS

Twenty-four male white rats were ordered for this experiment. Twelve of them were obtained from the Animal Breeding Establishment when they were 54-58 days, and the remaining 12 were obtained when they were 138-142 days old. They were housed in individual cages throughout the entire experiment with water freely available, and each was given 12 gm dry rat food immediately after it had completed its daily training.

APPARATUS

As in Experiment 1 of Chapter VII.

PROCEDURE

In this experiment, a 4 x 4 x 53 inch straight runway, with a food cup at each end identical to the one in the temporal maze, was used in the preliminary training. On each day S was placed in the middle section of the runway, and was then required to run from one end to the other until ten pieces of spaghetti, which were delivered from the Spaghetti Gun whenever S had run up to each food cup from the other end, were obtained. The preliminary training lasted for 11 days, and on the last three days, three extra runs were allowed for Ss that were relatively timid. At the end of this preliminary training, all Ss were eager to run for spaghetti.

After the preliminary training, Ss of each age group were randomly divided into two equal groups. One of them was trained under 4 x (3G 3F) schedule and the other group under 2 x (6G 6F) daily, except on the first five sessions, in which each received only half of these training trials, i.e., it was trained either under 2 x (3G 3F) or (6G 6F) schedules. Thus the numbers of total trials as well as the number of guided and free trials were equal for each group on each training session. The criterion of learning was five consecutive correct runs, and the guidance was discontinued as soon as the criterion was reached. On each post-criterion session, S was run a daily session of 30-50 free trials (the number of which depended upon S's performance), for at least five sessions. The treatments for each age group were made as similar as possible.

RESULTS

ACQUISITION

Age factor. Since the number of guided and free trials were equal for each training schedule, comparison in terms of the numbers of total trials to criterion should be sufficient. As a test of the age differences in learning the two-turn task, a comparison of the results for the young and the old Ss (irrespective of their training Schedules) is given below:

Age	Total trials to criterion		Total time to criterion		Average time per session	
	Mdn	Range	Mdn	Range	Mdn	Range
Young	897	522-1034	307.5	243-526	8.1	6.4-13.6
Old	974	525-1668*	285	182-372	6.5	4.2- 8.2

* S that received 1668 total trials failed to reach the criterion.

Mann-Whitney U tests indicated that there were no significant differences between groups in terms of the numbers of total trials to criterion ($U=71$, $p>.10$), and total time to criterion ($U=51$, $p>.10$), but the older Ss significantly took less time to complete each training session (average time) ($U=23$, $p<.02$). This difference between two age groups in the average time score may be due to differences in motivation level, which was not rigorously controlled.

In addition to the possibility that there are indeed no significant differences to be found between these two age levels (at the beginning of the experimental

training, the young rats were about 70 days old, and the old Ss about 154 days old), failure to obtain age difference may be also due to the relatively long period of training required (about three months), which might confound the results. Perhaps experiments of this kind should be delayed until a more effective training schedule has been determined.

Training schedules. A comparison for effectiveness of these two training schedules (irrespective of age factor) on learning the task is presented below:

Schedules	Total trials to criterion	Total time to criterion	Average time per session
	Mdn Range	Mdn Range	Mdn Range
4 x (3G 3F)	876 619-1398	297.5 182-372	7.2 4.2-8.7
2 x (6G 6F)	1055 522-1668*	311.5 201-526	7.7 5.6-13.6

* S that received 1688 trials failed to reach the criterion.

Mann-Whitney U tests showed that there were no significant differences between groups in terms of these three scores ($U=58$, $p>.10$; $U=51$, $p>.10$; $U=52$, $p>.10$, respectively).

POST-CRITERION PERFORMANCE

An unexpected interesting phenomenon was observed during post-criterion sessions, which seems to suggest that some uncontrolled factors were operating during the course of maze training. It was found that on most of the post-criterion sessions, Ss would usually perform

reasonably well at the early stage of the daily session, but would suddenly shift to an apparently stereotyped unadaptive behaviour pattern, namely, repeatedly committing one-turn errors without showing any sign of improving. What triggered this sudden change of behaviour is unknown, but it seems impossible that it was from the external environment, which was relatively constant throughout each daily session. Furthermore, this instability could not be altered even after a very extensive period of training (seven Ss had been extensively trained for 21 to 33 post-criterion sessions without any sign of steady improvement). Some typical examples are sufficient to illustrate the performance:

Response sequence*	
a.	during the first five post-criterion sessions (from difference Ss):
(i)	5E(1) 3C 1E(1) 22C 19E(1)
(ii)	1E(1) 1C 1E(1) 2C 4E(1) 12C 25E(1)
(iii)	2E(1) 14C 1E(1) 23C 10E(1)
(iv)	15C 25E(1)
b.	after extensive training (from the same S)
(i)	1E(1) 17C 1E(1) 1C 2E(1) 1C 25E(1) (28th session)
(ii)	2C 1E(1) 4C 2E(1) 31C (29th session)
(iii)	23C 2E(1) 2C 23E(1) (30th session)

* No S was allowed to commit more than 25 consecutive errors.

All 23 Ss in this experiment manifested this puzzling behavioural pattern. The numbers of its occurrence for each S in each group in the first five post-criterion sessions are given below:

Groups	The numbers of its occurrence for each S
4 x (3G 3F) (young)	3; 3; 4; 4; 4; 5.
2 x (6G 6F) (young)	3; 4; 4; 4; 5; 5.
4 x (3G 3F) (old)	4; 4; 4; 5; 5; 5.
2 x (6G 6F) (old)	2; 3; 3; 4; 5; *.

* not available for S that did not reach the criterion.

EXPERIMENT 2

The main purpose of this experiment was to compare for effectiveness three training schedules with $G/F=1$: 4 x (2G 2F), 2 x (4G 4F), and (8G 8F), on mastering the two-turn task.

SUBJECTS

Twenty-four male white rats about 14 weeks old at the beginning of the experimental training were used. They were housed in individual cages with water freely available, and were maintained on a daily ration of 11 gm dry rat food. On the first 29 training sessions, the daily ration was given immediately after Ss had completed their daily training, and from the 30th session, it was given at least 20 minutes after Ss' daily training session.

APPARATUS

As in Experiment 1.

PROCEDURE

In this experiment, the preliminary training was carried out entirely in the temporal circular maze. On day 1, Ss were allowed to run either five free trials or five minutes, whichever came first, in the maze; from day 2 to day 9, they were run five free trials each day. During the preliminary training spaghetti was given at the end of each trial irrespective of Ss' performance. From day 1 to day 4 spaghetti was given manually, and from day 5 to day 9 it was delivered from the Spaghetti Gun. It was found that, manual delivery of spaghetti on the first 4 days did reduce some undesirable effect caused by the operation of the Spaghetti Gun. On day 5 when spaghetti was delivered for the first time from the Spaghetti Gun, only five Ss failed to pick up spaghetti (presumably frightened by the noise of the operation of the Spaghetti Gun). Three extra free trials were given to those timid Ss from day 6.

After preliminary training, Ss were randomly divided into three equal groups and were trained under the 4 x (2G 2F) (Group I), 2 x (4G 4F) (Group II), and (8G 8F) (Group III) schedules. As in Experiment 2 of the previous chapter, minor variations from the schedules were allowed, namely, when the last free trial of a block was a correct one, an extra free trial (or trials as the case might be) was given, and if two or more (but less than five) correct runs were made, further free trials were

given until two consecutive errors occurred. The criterion of learning was, again, five errorless runs; guidance was discontinued when the criterion was attained.

In the criterion session, 20 extra free trials were given immediately following the fifth criterion trial, and on the following sessions, S was run daily sessions of 30 free trials until the criterion of stable performance specified in Experiment 2 of Chapter VII were attained. However, the procedure was not fully applied to all Ss, since the present experiment was discontinued before all Ss were able to reach the criterion of learning for reasons described below.

RESULTS

ACQUISITION

Since the performance of some Ss was very similar to that shown by Ss of Experiment 1, suggesting that some unknown variables might be involved, it was decided to discontinue this experiment when all Ss in Group I had reached the criterion of learning. By the time that all Ss in Group I were able to reach the criterion, there were still one S in Group II and three in Group III who failed to do so. The numbers of total trials and the total time taken to reach the criterion, and the average time taken per session for each group are given below:

Treatments	Total trials to criterion		Total time to criterion		Average time per session	
	Mdn	Range*	Mdn	Range*	Mdn	Range*
4 x (2G 2F)	680.5	492-1196	242	154-338	5.3	4.3-6.7
2 x (4G 4F)	835.5	639-1297	272.5	200-671	5.9	4.7-8.3
(8G 8F)	1040	687-1280	376	214-649	5.6	5.1-8.1

* Scores for Ss that failed to reach the criterion were included.

Kruskal-Wallis one-way analysis of variance indicated that there were no significant differences amongst groups in terms of the above scores ($H=4.30$, $df=2$, $p>.10$; $H=4.54$, $df=2$, $p>.10$; $H=2.25$, $df=2$, $p>.30$, respectively), although the scores show that Group I tends to be superior.

POST-CRITERION PERFORMANCE

Since some Ss in this experiment also manifested the strange behaviour pattern observed in Experiment 1, which suggest complications of unknown factors, and the experiment was discontinued before all Ss were able to reach the criterion of learning, it was decided not to compare the results on post-criterion performance amongst groups. However, examination of the data shows that the tendency of manifesting the unadaptive response of one-turn errors was weaker for Ss of this experiment than that of Ss of Experiment 1:

- (1) In this experiment, only 13 out of 20 Ss that reached the criterion manifested, at least once during the course of post-criterion

training, this behaviour pattern, while all 23 Ss in Experiment 1 did.

- (2) For nine Ss that manifested this behaviour pattern within the first five post-criterion sessions, the instances of its occurrence for each S range from 1 to 2 (median:2) which are far less than those of Experiment 1 (see results of Experiment 1 above).
- (3) Ten out of these 13 Ss were able to attain the criteria of stable performance, namely, at least 80 per cent correct trials for five consecutive sessions, and the range of the number of correct trials made in these five sessions was not larger than four, after 4 to 11 sessions (median at 7.5) of post-criterion training, while none in Experiment 1 was able to do so.

DISCUSSION

The results of these two experiments seem to suggest that there are some uncontrolled factors operating in the course of training, which affected the relative rate of reaching the criterion of learning, and the stability of post-criterion performance. Comparisons between the results of these two experiments and those of Experiment 2 of Chapter VII, in which the schedules 3 x (4G 2F), 3 x (4G 4F), and 3 x (2G 2F) were studied, are of some interest:

- (1) the numbers of total trials required to reach the criterion of learning by Ss of

these two experiments were more than twice those needed by Ss of Experiment 2 of the previous chapter, and

- (2) all 23 Ss of Experiment 1 and 13 of Experiment 2 of this chapter which reached the criterion of learning manifested the unadaptive tendency of continuously committing one-turn errors on some post-criterion sessions, while none of the 24 Ss in the experiment of the previous chapter did so (the longest consecutive errors observed was seven, which was committed right at the beginning of that training session).

The similarities between the results of these two experiments, i.e., slow acquisition of the skill and unstable post-criterion performance, seem to suggest that some common factor (or factors) might be operating. What were the possible reasons for these consistent bad results? Besides the genetic factors which are hard to track down, differences in the procedures may be worthy of consideration. There are two aspects of procedure which were common to these two experiments, but differed from all the others that did not result in these undesired results. (i) Subjects of these two experiments were housed individually, while Ss of the other experiments were housed in groups. However, there seems to be no good reasons to suspect that this difference per se would be the relevant factor for the observed results. (ii) In these two experiments, Ss were given their daily rations immediately after they had completed their daily training, while for Ss of the other experiments, there was, on most of the occasions,

an interval between the end of daily training and the feeding, since they were housed in groups and were fed only when all Ss in each group had completed their daily training. There is indirect evidence, namely, the difference between Experiments 1 and 2 in the post-criterion results (see the results on post-criterion performance in Experiment 2 above), which suggests this condition might be a relevant factor.

In Experiment 1, the feeding procedure was exercised throughout the entire experiment, and a severe tendency to sudden changes to the unadaptive behaviour of committing one-turn errors, which could not be changed, was observed. In Experiment 2, the feeding procedure was changed from the 30th training sessions, when the first S that reached the criterion of learning manifested the unadaptive behaviour, which made this writer suspect the possible involvement of the factor, and a milder tendency of continuously committing one-turn errors was observed. Whether this is an accurate guess or not, and if so how it operates to produce such a profound effect on performance remains to be determined experimentally. However, for practical purposes, it seems advisable to avoid this possible complication by imposing a time interval between the end of training session and the beginning of daily feeding.

Although there is evidence showing that some confounding factors were involved in these two experiments, which makes it impossible to arrive at a definite conclusion on the relative effect of the length of the runs of the guided and free trials on learning the two-turn task, the trends of the results of both

experiments seem to indicate that, at least in terms of the numbers of total trials score, the short runs might be more effective than the longer runs. Further work on this problem is necessary.

CHAPTER IX

EFFECT OF ALCOHOL UPON THE PERFORMANCE OF THE
TWO-TURN TASK

Dr Krech:, and as I look over most of the work on the effects of drugs on behaviour, I am struck with what one might almost call an anti-intellectualism among researchers,....

Dr Miller: ...I agree with you and would like to support your view....But I think the reason historically perhaps is the lack of adequate instruments.... (Farber and Wilson, eds, 1961, p.125-7).

The above dialogue, which is an extract from a symposium on Man and Civilization: Control of the Mind (Farber and Wilson, 1961), clearly depicts the trend of the studies of the effects of drugs on behaviour, and points out one reason for the tendency of overemphasising the studies of the effects of drugs on emotional and motivational aspects of behaviour.

It has already been shown in Chapter V that the behaviour of the white rat in the temporal circular maze can not be accounted for entirely in terms of sensory-motor principles, and some ideational or symbolic processes may be responsible for the successful performance. In addition to this, the maze seems to possess several advantageous features, which suggest that the use of this maze in psychopharmacological studies may be advantageous:

- (1) It has been shown in Chapter VII that the performance on the two-turn task can be very

stable, and so meets one of the basic requirements of behavioural techniques for assessments of the actions of drugs on animal behaviour.

- (2) Like a Skinner box, the maze possesses advantages such as the elimination of handling of S during each performance session, and the great adaptability to automation of delivery of rewards and recording of performance.
- (3) This maze technique would provide not only the measure of response rate, but also something about the nature of each response (e.g., correct or erroneous). Furthermore, distinctions can be made between the types of errors that occur. For example, on the two-turn task, the errors may be underestimation (e.g., one-turn errors), or overestimation (e.g., three-turn errors). Thus the maze possesses some built-in advantages which would provide more sensitive assessments of the differential effects of drugs on behaviour.

The main purpose of the experiments reported in this chapter is to investigate this potentiality of the temporal circular maze in a more direct way, i.e., to study effects of a drug (alcohol) on the performance of the two-turn task. Alcohol was selected solely for practical reason that it was more easily available than any other drug.

EXPERIMENT 1

The purposes of this experiment were to examine the stability of the performance of the two-turn task in control sessions, especially for each individual S, and to study the effects of two concentrations of alcohol on the performance of white rats doing the two-turn task.

METHOD

SUBJECTS

Four male white rats of Experiment 1 of Chapter VII were selected for this experiment. They were about 25 weeks old at the beginning of the experimental treatments, were housed in groups of two with water freely available, and were given an average ration of 12 gm (24 gm per group) dry rat food at the end of each daily session. Their weights were, for rats 24, 25, 26, and 27, 252, 253, 217, and 223 gm respectively at the beginning of this experiment.

APPARATUS

As in Experiment 1 of Chapter VII.

PROCEDURE

Pre-experimental maze training. These four Ss were selected from the previous experiment on the ground that they reached the criterion of learning at about the same time. The detailed training procedure has already been described in Chapter VII. Rats 24 and 26 were trained under the 3 x (6G 6F) schedule and rats 25

and 27 under the 4 x (3G 3F) schedule. The numbers of total trials required for rats 24, 25, 26, and 27 to reach the criterion of learning were 702, 552, 652, and 606 respectively. After attaining the criterion, they were given a further 12 sessions of post-criterion training, each of which consisted of 50 free trials, before the experimental treatments started.

Experimental treatments. The whole of the present experiment was carried out in successive blocks of three sessions: control (injected with saline), alcohol, and no-treatment (no injection was given), i.e., on day 1 each S had a control session, on day 2 an alcohol session, on day 3 a no-treatment session, and on day 4, a control session again, and so on. Thus there were always three days intervening between alcohol sessions. However, there was one exception to the above procedure. On day 19 (a control session), rat 27 appeared to be very weak, and would not run the maze either; thus it was allowed to rest for two days, and was then run, on day 22, a no-treatment session. A new sequence of control, alcohol, and no-treatment sessions was started on day 23.

On control and alcohol sessions, each S was injected intraperitoneally with 2 ml isotonic saline, and alcohol solution respectively three minutes before it was put into the maze. The concentrations of the alcohol used were five per cent, ten per cent, and 15 per cent by volume of absolute alcohol in isotonic saline; after conducting trials with rats 26 and 27, the five per cent concentration was found to be

ineffective, so this dosage was discontinued. The injection order for each concentration for each S is presented in Table 17. Except for a few alcohol sessions which were terminated because S showed no sign of recovery from the effect of alcohol after 45 minutes in the maze, a task limit of 50 free trials for each session was adopted. Food reward (1 cm raw spaghetti) was given, as in maze training, whenever a correct run was made.

RESULTS AND DISCUSSION

CONTROL SESSIONS

In this experiment, three kinds of scores were taken: (i) total time taken to complete 50 free trials, (ii) the numbers of total correct trials made in each session, and (iii) the numbers of total trials (correct and erroneous) made in the first 15 minutes of each session. The scores for each S on all control sessions are summarized in Table 18. The first part of Column A, i.e., the number of correct trials made in each successive block of ten free trials, give a detailed account of the distribution of the correct trials. It is clear that for all Ss, the performance in the middle 30 trials was more stable than the first and the last ten trials. The scores in Column B, i.e., the numbers of total trials (correct and erroneous trials) made in the first 15 minutes, have the advantage of taking time into consideration, thereby permitting the assessments of any general excitatory or depressant effect of drugs on the performance.

TABLE 17
TOTAL TIME SCORE (IN MINUTES) FOR FOUR RATS ON EACH ALCOHOL SESSION AS A FUNCTION OF THREE
DOSAGE LEVELS AND INJECTION ORDER

Injection order	Subjects							
	24		25		26		27	
	dosage level	Time score	dosage level	Time score	dosage level	Time score	dosage level	Time score
1	15%	45*	10%	45*	5%	18	5%	27
2	10%	22	10%	29	10%	21	10%	50
3	15%	55	15%	45*	15%	25	15%	45*
4	10%	29	10%	33	10%	31	10%	36
5	10%	23	10%	23	10%	29	10%	22
6	10%	22	10%	26	10%	24	10%	18
7	10%	22	15%	45	10%	24	10%	22
8	15%	30	15%	39	15%	31	15%	45*
9	15%	37	15%	27	15%	58	15%	64
10	15%	38	15%	43	15%	47	15%	44
11	**		**		15%	38	15%	51

* The session was discontinued after 45 minutes because of no sign of recovery from the effect of alcohol.

** 5% concentration not used for these two Ss.

TABLE 18
DATA ON CONTROL SESSIONS FOR THE FOUR RATS

Subjects	No. of observations	Total time scores (in minutes) (mean±SD)	A No. of correct trials (Value at top is median, at bottom is range)					
			No. of correct trials made in successive blocks of ten trials					No. of total correct trials out of 50 trials
			1st	2nd	3rd	4th	5th	
24	10	23.7±2.5	10 9-10	10 9-10	10 9-10	10 9-10	10 8-10	49.5 47-50
25	10	27.5±2.9	9 8-10	10 9-10	10 9-10	10 9-10	10 8-10	48 46-49
26	11	24.7±1.2	9 8-10	10 9-10	10 9-10	10 9-10	10 8-10	48 46-50
27	11	23.6±5.2	8 5-10	10 0	10 0	10 9-10	8 8-10	47 45-49

Subjects	No. of observations	Total time scores (in minutes) (mean±SD)	B No. of trials made in the first 15 minutes (mean ± SD)		
			No. of correct trials	No. of erroneous trials	
			No. of correct trials	No. of total trials	
24	10	23.7±2.5	32.9±4.5	0.6±0.8	33.5±4.3
25	10	27.5±2.9	26.2±3.3	1.1±0.6	27.3±3.0
26	11	24.7±1.2	32.0±1.8	1.4±0.7	33.4±1.7
27	11	23.5±5.2	31.5±6.0	2.3±1.9	33.8±6.4

The values of standard deviations and the ranges give a rough estimation of the stability of Ss' performance on all control sessions, which cover a period of 29-32 days. It can be seen from Table 18 that the performance of these four Ss was very stable and reliable; amongst them, the performance of rat 27 was the least stable of all. Examination of the data on all control sessions for all Ss shows that the performance of all Ss has already reached its ceiling at the beginning of the experimental treatments, and a general practice effect can thus be neglected.

EFFECTS OF ALCOHOL

A comparison of the mean total time (in minutes) taken by each S to complete the daily session of 50 free trials on the three experimental conditions (i.e., control, ten per cent alcohol, and 15 per cent alcohol) is given below:

Subjects	Control		10% alcohol		15% alcohol	
	Mean	Range	Mean	Range	Mean	Range
24	23.7	18-26	23.6	22-29	40	38-55
25	27.5	23-31	31.2	23-45*	38.5	27-45*
26	24.5	23-26	25.8	21-31	39.8	25-58
27	23.5	15-35	30.2	18-50	53	44-64

* session was terminated after 45 minutes.

It appears that the time taken to complete each session is in direct proportion to the concentrations of alcohol

given. A Friedmann two-way analysis of variance by ranks showed that overall effect was significant ($\chi^2_r=8$, $df=2$, $p=.0046$).

The time taken to complete each alcohol session for each S are presented in Table 17. It is evident that at ten per cent concentration, the effect varied with Ss: there was scarcely any effect at all on rats 24 and 26, but on earlier sessions where the alcohol injection was given, the time scores for rats 25 and 27 were clearly larger than their control values (see Table 18). At 15 per cent concentration the time scores for all Ss were clearly increased, (compare with the range scores of control sessions given above); again, the effect seems to be more severe on earlier injection sessions than on the later ones.

A comparison of the means of the numbers of correct trials made in 50 free trials for each S under the three experimental conditions is presented below:

Subjects	Control		10% alcohol		15% alcohol	
	Mean	Range	Mean	Range	Mean	Range
24	49	47-50	47.2	45-49	34.6	0*-48
25	48	46-49	47.5	0*-50	36.2	0*-47
26	47.6	46-50	48	46-50	43.4	39-48
27	47.5	45-49	44.4	39-48	27.4	0*-46

* based on the scores of the incomplete session.

It is clear that the numbers of correct trials decreased as the dosage level increased. A Friedmann two-way analysis of variance indicated that the overall effect was significant ($\chi^2_r=6.5$, $df=2$, $p=.042$). Examination of

individual scores (see Appendix IIIa), again suggests that at the ten per cent level, rats 25 and 27 were severely affected on the first drug session, and at the 15 per cent level, it is quite evident that all Ss were affected by the alcohol especially on the earlier drug sessions.

Examination of the distribution of the correct trials made on the alcohol sessions seems to suggest that the detrimental effect of alcohol was more evident on the first ten trials than on the remaining 40 trials (see Appendix IIIb), i.e., on alcohol sessions Ss committed more errors on the first ten trials.

It was found during the experiment that the above two scores, i.e., the number of total correct trials and the distribution of these correct trials, were not so appropriate for the assessment of the effects of alcohol. On an affected session, after they had completed one or two trials involving one-turn errors, Ss would usually sit at the entrance or at the food cup until the depressant effect of alcohol wore off. Following this period, they would generally be able to run the maze with considerable efficiency, although at a slow pace. Thus the number of correct trials and the distribution of these trials were generally not so much affected. In this respect, the score on the number of total trials made in the first 15 minutes may be a more adequate one.

The data for each S on the numbers of total trials, the numbers of correct trials, and the numbers of errors made in the first 15 minutes on the three experimental conditions are presented in Table 19, which shows that

TABLE 19

DATA ON THE THREE EXPERIMENTAL CONDITIONS (CONTROL, TEN PER CENT ALCOHOL, AND 15 PER CENT ALCOHOL)
FOR THE FOUR RATS

Subjects	Control		10% alcohol		15% alcohol	
	Mean	Range	Mean	Range	Mean	Range
NUMBER OF TOTAL TRIALS						
24	33.5	27-40	31.2	22-35	10.4	2-22
25	27.3	24-31	20.4	5-31	9.8	0-29
26	33.4	31-35	30.8	22-36	17.2	3-30
27	33.8	27-50	23.6	6-44	1.6	0-5
NUMBER OF CORRECT TRIALS						
24	32.9	27-40	28.4	19-33	6.2	0-20
25	26.2	22-31	17.8	0-31	6.8	0-27
26	32	29-34	28.8	20-36	13.4	0-27
27	31.5	26-47	19.2	0-39	0	0
NUMBER OF ERRONEOUS TRIALS						
24	0.6	0-2	2.8	1-5	4.4	2-7
25	1.1	0-2	2.6	0-5	3.8	0-5
26	1.4	0-2	2.0	0-4	3.8	1-6
27	2.3	1-5	4.4	2-6	1.6	0-5

the detrimental effect of alcohol is in direct proportion to its concentration. The Friedmann two-way analysis of variance indicated that the overall effects were significant in terms of the numbers of total trials and the numbers of correct trials ($X_r^2=8$, $df=2$, $p= .0046$, and $X_r^2=8$, $df=2$, $p= .0046$ respectively), but not so in terms of the error score ($X_r^2=3.5$, $df=2$, $p= .273$). It is clear from Table 19 that failure to obtain a significant overall difference in the error score is mainly due to the results of rat 27, the response of which on 15 per cent alcohol sessions was severely suppressed, so that the numbers of errors committed were reduced. In view of the trend shown by rats 24, 25, and 26, it would appear that alcohol may also exert a detrimental effect on performance in terms of the number of errors committed.

Figure 8 shows two typical effects of these two concentrations of alcohol on the performance of the white rats in the first and the second 15 minutes. The results of rats 24 and 26 were of one type, and the results of rats 25 and 27 were of the other. It can be seen from Figure 8 that rat 24 (as well as 26) was relatively tolerant of the ten per cent concentration, but rat 25 (as well as 27) was severely affected at least on the first injection session; it made not a single correct trial but only errors during the first 30 minutes of the first alcohol session. A dosage at the 15 per cent level was capable of depressing the number of total trials for all Ss, and again, the effect was more severe with the earlier injections.

The results of this experiment clearly demonstrated that a relatively stable response pattern can be

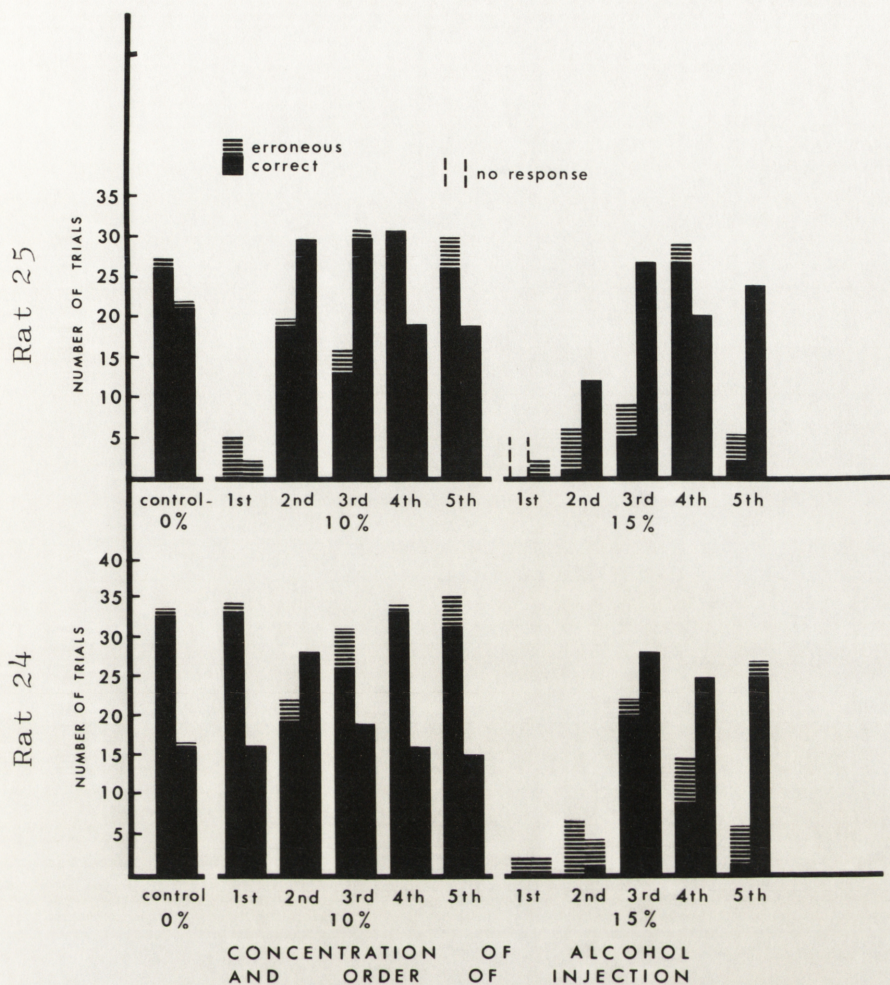


FIGURE 8

Histograms showing the numbers of total trials (in terms of erroneous and correct trials) made in the first 15 minutes (the first column of each block) and the second 15 minutes (the second column of each block) on each alcohol session in comparison with the mean value of control sessions. The control data shown in the first block represent the mean of 10 control sessions. A task limit of 50 trials on each session may account for the general drop of the numbers of responses in the second column of each block.

obtained on control sessions for each individual S over a relatively long period of time (29-32 days), which strongly suggest the feasibility of using this maze technique in the study of the effects of drugs on the cognitive aspect of animal behaviour. Although only four Ss were used in this experiment, the effect of alcohol on the performance of the two-turn task was quite clear. At the 15 per cent concentration, it increased the total time taken to complete 50 free trials, which was similar to the finding of Miller and Miles (1936) using an alley maze, depressed the number of total trials (as well as the number of correct trials), which is similar to the finding of Sidman (1955) using a Skinner box situation, and possibly caused the number of one-turn errors to increase. At ten per cent concentration, however, the effect seems to have varied with each individual S.

EXPERIMENT 2

The alcohol-tolerance effect, i.e., greater sensitivity to an initial dose than to the same dose repeated later, which has been noted in Experiment 1, is a familiar phenomenon. But how much do we know about its nature? Can the phenomenon be explained entirely in terms of physiological or biochemical principles? Or is it necessary to invoke some behavioural principles, e.g., habituation? The purpose of this experiment was to investigate some aspects of this interesting problem.

METHOD

SUBJECTS

Twelve male white rats from Experiment 2 of Chapter VII were used. They were 19-20 weeks old at the beginning of the experimental treatments, were shifted to individual cages 6-8 days before the experiment treatments began, and were given a daily ration of 12 gm dry rat food. Water was freely available all the time.

APPARATUS

As in Experiment 2 of Chapter VII.

PROCEDURE

Pre-experimental maze training. Detailed training procedure has already been described in Chapter VII. Six Ss were trained under the 3 x (4G 2F) schedule, and the other six under the 3 x (4G 4F) schedule. After reaching the criterion of learning, each S received ten to 16 sessions of post-criterion training before the experimental treatments began. The numbers of post-criterion sessions depended upon the stability of S's performance. For the first six to 11 sessions daily training consisted of 30 free trials; for the remaining four to five sessions training was discontinued after ten minutes of training each day. After the completion of post-criterion training, the performance in the maze was very stable and efficient (each S was able to make at least 80 per cent correct trials). Before the experimental treatments started, the 12 Ss were randomly

divided into two equal groups. However, the background of the maze training was balanced for each group, i.e., each group had half of the Ss trained under the 3 x (4G 2F) schedule and the other half under 3 x (4G 4F).

Experimental treatments. The whole of the present experiment was carried out in successive blocks of three sessions: on day 1, each S had a control session (injected with isotonic saline), on day 2, an alcohol session, on day 3, a no-treatment session (no injection was given), and on day 4, a control session again, etc. On control and alcohol sessions each S was injected intraperitoneally with 10 ml/kg of isotonic saline and alcohol solution (15 per cent by volume of absolute alcohol in isotonic saline), respectively.

For each S isotonic saline was injected ten minutes before it was introduced into the maze. For Ss of the Behavioural Group, the alcohol solution was invariably given ten minutes before they were put into the maze. However, for Ss of the Physiological Group, on the first three alcohol sessions, the alcohol solution was given one minute after the session was completed, and on the fourth alcohol session it was given, as in the Behavioural Group, ten minutes before this session started.

Thus on the fourth alcohol session, Ss of both groups had experienced equal numbers of alcohol injections and equal experience with the maze, but differed in that Ss in the Behavioural Group had actually run the maze while under the influence of alcohol on the first three alcohol sessions, but Ss in the

Physiological Group experienced the alcohol alone (they were returned to their home cages after injections). If physiological or biochemical principles were sufficient to account for the tolerance effect, no significant difference in performance would be expected between the two groups on the fourth alcohol session. On the other hand, if there is significant difference between these two groups, then some psychological principles may have to be postulated.

On each session S was allowed to run the maze freely for ten minutes, and reward was given at the end of each correct trial. No effort was made to control the intertrial interval.

RESULTS AND DISCUSSION

The medians of the mean scores of the control and no-treatment sessions for the Behavioural Group are the following:

Treatments	No. of correct trials		No. of errors		No. of total trials	
	Mdn	Range	Mdn	Range	Mdn	Range
control	30.1	23.8-43.5	2.5	1.4-4.5	33.5	26.5-44.8
no-treatment	30.3	20-35	3.5	1.0-8.0	32.1	22.3- 43

Wilcoxon matched-pairs signed-ranks tests (Siegel, 1956, p.75) indicated that there were no significant differences between the medians of the mean scores of the control and the no-treatment sessions ($T=2$, $p>.05$, and $T=1$, $p>.05$ respectively). However, individual scores indicated that the performance of two Ss on the first no-treatment session, and the performance of the other S on the second no-treatment session was very poor. For example, errors committed by these three Ss on the first or the second no-treatment sessions were 30 per cent, 40 per cent, and 50 per cent of their total trials respectively, while their error scores on four control sessions ranged from three per cent to 7.8 per cent, from 9.3 per cent to 17 per cent, and from two per cent to 4.6 per cent respectively.

The medians of the mean scores, for the Physiological Group, on the control sessions, the first three alcohol sessions (injected at the end of each session), and the no-treatment sessions are presented below:

Treatments	No. of correct trials		No. of errors		No. of total trials	
	Mdn	Range	Mdn	Range	Mdn	Range
control	33.6	28.3-36.2	2.8	1.8-5.3	36	32-41.8
alcohol	34	27 -38	2.8	2 -5.3	36.7	30-43
no-treatment	31.8	26 -36	2.5	2 -4.5	34.9	29.5-40.5

The Friedmann two-way analysis of variance indicated that there were no significant differences among the

medians of these three treatments on the three scores ($X_r^2=2.33$, $df=2$, $p=.430$, $X_r^2=4.33$, $df=2$, $p=.142$, and $X_r^2=4.33$, $df=2$, $p=.142$, respectively). It is also interesting to note that not a single S showed poor performance on any no-treatment sessions for this group.

Statistical analysis of the scores on the successive control sessions justifies the assumption that the performance has reached its ceiling (i.e., the sequential effect is not significant), and the general practice effect can thus be neglected. The sequential effect of these four control sessions was tested by the Friedmann two-way analysis of variance, the results of which are given below:

Groups	No. of correct trials	No. of errors	No. of total trials
Behavioural	$X_r^2=1.25$, $p>.70$	$X_r^2=5.35$, $p>.10$	$X_r^2=3.95$, $p>.20$
Physiological	$X_r^2=5.35$, $p>.10$	$X_r^2=3.35$, $p>.30$	$X_r^2=6.25$, $p>.10$

($df=3$, for all tests)

The errors committed on the control sessions were mainly one-turn errors; only two three-turn errors were committed by two Ss (one from each group).

Table 20 presents the data on alcohol sessions for the Behavioural Group and the Physiological Group the mean control scores are also presented for comparison. The errors committed on the alcohol sessions were mainly one-turn errors, and only one three-turn error was recorded. Unless otherwise specified, the p values reported throughout the following sections were obtained with the Fisher exact probability test.

TABLE 20

PERFORMANCE ON CONTROL AND ALCOHOL SESSIONS FOR THE BEHAVIOURAL GROUP (SUBJECTS GIVEN 1.2 G/KG ALCOHOL I. P., TEN MINUTES BEFORE THE EXPERIMENT) AND FOR THE PHYSIOLOGICAL GROUP (SUBJECTS WERE TREATED WITH 1.2 G/KG ALCOHOL I. P., AFTER EACH OF THE FIRST THREE SESSIONS, AND IN THE FOURTH SESSION THE SAME DOSE OF ALCOHOL WAS GIVEN BEFORE THE SESSION AS IN THE BEHAVIOURAL GROUP). THE CONTROL SCORE FOR EACH SUBJECT IS THE MEAN SCORE OF ALL FOUR CONTROL SESSIONS (SUBJECTS WERE INJECTED WITH ISOTONIC SALINE).

Treatments	No. of correct trials		No. of errors		No. of total trials	
	Mdn	Range	Mdn	Range	Mdn	Range
BEHAVIOURAL GROUP						
Control	30.1	23.8-43.5	2.5	1.5-4.5	33.5	26.5-44.8
Alcohol injection No.:						
1	0.5*	0-23	6	2-18	8*	2-29
2	9*	1-24	16.5*	8-24	29	10-38
3	23.5*	1-37	11*	2-20	33	21-49
4	26	2-33	10	4-23	34	25-41
PHYSIOLOGICAL GROUP						
Control	33.6	27-36.2	2.8	1.8-5.2	36	32-41.8
Alcohol injection No.:						
4	3*	1-9	22*	1-50	27.5	3-53

* $p < .05$ (two tailed, sign test) compared against control.

TOLERANCE EFFECT

The results on the alcohol sessions of the Behavioural Group clearly show that the effect of alcohol gradually reduced as a function of the numbers of injection. A Friedmann two-way analysis of variance by ranks showed that the sequential effect of alcohol injections was significant in terms of the correct and the total scores ($X_r^2=14.6$, $df=3$, $p<.005$, and $X_r^2=12.2$, $df=3$, $p<.01$, respectively), but not in terms of the error score ($X_r^2=4.75$, $df=3$, $p<.20$). Sign tests (Siegel, 1956, p.68) indicated that for the correct scores, the second session was significantly better than the first ($p= .031$, one tailed), and the third better than the second ($p= .031$, one tailed), but there is no significant improvement on the fourth session over the third ($p= .109$). For the total score, the most affected session is the first; the second session was significantly better than the first ($p= .016$, one tailed), but there was no significant improvement on the third over the second ($p= .344$, one tailed), and the fourth over the third ($p= .344$, one tailed). Although analysis of variance failed to reach significance for the error score, it is worth noting that the performance on the second session was significantly worse than that on the first ($p= .016$, one tailed), i.e., Ss committed more errors on the second session than on the first. This may be due to the fact that on the first alcohol session Ss' responses were greatly suppressed, and consequently the numbers of errors committed were fewer. It has been shown that the performance of Ss had already reached its ceiling, hence this sequential

effect of alcohol can not be attributed to the general practice effect. Thus the alcohol-tolerance effect, defined here as greater sensitivity to an initial dose than to the same dose repeated later, seems to have been experimentally demonstrated. An important implication of this result is that in studying the effect of alcohol on performance, one should take this sequential effect into consideration. For example, Stebbin, Lundin and Lyon (1960) found in their experiment that the effect of alcohol produced only 9.5 per cent decline in responding, while Sidman (1955) found a 50 per cent decline. Examination of the procedures showed that the difference may be partially due to the fact that in Sidman's study the comparison was based on the first injection session, while in the study of Stebbin et.al., the comparison was based on the final session.

NAIVE VERSUS EXPERIENCED

Comparison between the performance on the first alcohol session of the Behavioural Group and that on the fourth alcohol session of the Physiological Group is of some interest, because it was the first time Ss of both groups ran the maze under the influence of alcohol, but Ss of the Physiological Group had experienced alcohol beforehand. The results show that the response rate (number of the total trials made in ten minutes) of experienced Ss was significantly higher (median: 27.5) than the naive Ss (median: 8) ($p < .05$). In terms of correct trials the Physiological Group were slightly but not significantly better than the Behavioural Group ($p > .05$). However, comparison of error scores revealed

that the experienced Ss committed significantly more errors, ($p < .05$). Thus this result suggests that the effect of having experienced alcohol beforehand seems to reduce the general depressant effect of alcohol on performance, but does not improve substantially the efficiency of S's performance.

BEHAVIOURAL VERSUS PHYSIOLOGICAL EXPLANATION

The problem to be considered in this section is whether the tolerance effect can be explained entirely in terms of physiological or biochemical principles. Comparison is made on the fourth alcohol session of the Behavioural Group and the Physiological Group, which are similar in that Ss of both groups had experienced equal numbers of alcohol injection and equal experience with the maze, but differ from each other in that Ss of the Behavioural Group had extra experiences of running the maze while under the influence of alcohol on the first three alcohol sessions. The results show that for the response rate there was no significant difference between groups ($p > .05$). However, comparisons in terms of the correct and the error scores showed that the performance of Ss of the Behavioural Group was significantly better than that of the Physiological Group ($p < .05$), i.e., Ss in the Behavioural Group made more correct trials and committed fewer errors than Ss of the Physiological Group on the fourth alcohol session. Thus the results clearly show that Ss that had the opportunities to run the maze while under the influence of alcohol perform much better than Ss that had merely been accustomed to the same amount of alcohol but trained in a sober state.

These results together with those previously mentioned suggest two tentative conclusions:

- (1) The general depressant effect of alcohol, which is inferred from the change in the response rate, decreases as a function of the numbers of alcohol injections, but is independent of the effect of training under the influence of alcohol, i.e., mere experience of alcohol alone is sufficient to reduce the depressant effect of the drug. Thus physiological or biochemical mechanisms such as decreased absorption rate of stomach and intestine, or increased catabolism rate of alcohol might be sufficient to explain this type of tolerance effect.
- (2) Reduction in detrimental effect of alcohol on the proficiency of S's performance (as inferred from the number of correct and erroneous trials) is obtained only when the animal has repeated opportunities for running the maze while under the influence of alcohol. Being accustomed to alcohol alone is not sufficient to improve its proficiency. In order to explain this type of tolerance effect, physiological or biochemical mechanisms are not sufficient, some supplementary behavioural mechanisms, e.g., habituation may need to be postulated.

These results suggest that the effect of alcohol on performance is rather complex, and if a single measurement such as response rate is used many important aspects of the alcohol effects may be overlooked. For

example, in this experiment, if only the response rate measure had been used it might have been concluded that the physio-biochemical explanation is sufficient for the alcohol-tolerance effect. However, it can readily be seen that when additional data such as the number of correct trials are available additional behavioural principles are necessary.

EFFECT OF ALCOHOL ON PERFORMANCE AS COMPARED WITH CONTROL

The results discussed above have shown some complex features of the effect of alcohol on the performance. So far no comparison between alcohol and control sessions has been made. It is quite clear from Table 20 that the numbers of correct trials made by Ss of the Behavioural Group were significantly affected by alcohol on the first three sessions, and on the second and the third sessions they committed significantly more errors than they did on control sessions. Failure to obtain significant results on the first session is clearly due to the strong general depressant effect of alcohol, which is evident from the total-trial scores. The results for the Physiological Group are similar to those of the Behavioural Group, i.e., on the fourth alcohol session (the first in the maze) they committed more errors, made fewer correct trials than they did on the control sessions. Thus the effects of alcohol on performance of the two-turn task as compared with the control are: (i) to depress the response rate significantly on the early occasion, which confirms the finding of Experiment 1 and is similar to the Skinner box studies of Laties and Weiss (1962), Reynolds and Von Sommer (1960), and

Sidman (1955); (ii) to decrease significantly the number of correct trials and to increase the number of one-turn errors, which is similar to the finding of Miller and Miles (1936) in an alley maze situation.

CONCLUSION

Possible applications of the temporal circular maze in the behavioural drug study have been suggested. The results of these two experiments suggest that with more refinement, the temporal circular maze may provide a sensitive technique in the field of psychopharmacology. It has been shown in these two experiments that a relatively stable response pattern can be achieved, which meets one of the requirements of behavioural techniques to be used in drug studies. Furthermore, the maze also possesses the advantages of providing several types of measures at the same time, e.g., response rate, correct trials and errors, by which differential effect of drugs can be evaluated in detail. It has also been shown in Chapter V that the performance of the white rat in this maze situation is rather complex. The performance could not be accounted for entirely in terms of sensory-motor principles. It is thus expected that the maze may also provide a useful tool for the investigations of the effect of drugs on the cognitive and symbolic aspects of behaviour, which seem to have been less studied, possibly due to lack of adequate research instruments.

CHAPTER X

CONCLUSIONS

The aims of the present study were, on the one hand, to investigate counting ability in the white rat, which has not been so much studied by psychologists as other aspects of its behaviour, and on the other hand, to develop through this investigation desirable techniques or methods for studying representative or symbolic processes in the rat. We have learned a great deal about variables or conditions that affect learning of simple behaviour, such as bar pressing behaviour, choice making in a single unit T-maze, avoidance of threatening stimuli, etc. But will these variables or conditions affect complex behaviour in the same way as they do simple behaviour? An answer to this question would in part require adequate techniques for studying complex behaviour, which seem to be pressingly needed.

To these ends, the enclosed temporal circular maze, which possesses several useful features, was developed, and studies were made of the capacity of the white rat in this maze situation, the nature of the maze behaviour, the effectiveness of various training procedures, and possible application of this maze in studies of the effects of drugs on animal behaviour. The useful features of the temporal circular maze are: (i) exteroceptive cues and proprioceptive stimuli are not essential for successful performance, (ii) simplicity

of motor activity (only locomotion is required), (iii) minimal handling of animals during the course of daily training, and (iv) great possibility for automatic operations.

THE CAPACITY OF THE WHITE RAT

The most fundamental question in this study is whether the white rat is able to learn any task in this maze situation at all. The results (see Chapter IV) show that it is quite able to master tasks in this maze situation, which suggest that the ability of the white rat to learn tasks of only a temporal nature has been underestimated, possibly due to the inappropriate techniques employed in the previous investigations. One of the well-known techniques available is the double alternation problem. The results of studies using this technique showed that the rat was able to master this task with great difficulty (Hunter and Nagge, 1931; Livesey, 1965) but it was unable to extend the response sequence (e.g., RRLL), on which it was trained. This suggested that it was unable to learn the 'double alternation principle' but only learned to find the location in the series at which the response should be changed. A second method available is the modified multiple choice method devised by Atkins and Dashiell (1921), and their results suggested that the rat was just unable to master tasks presented in this maze situation. A third method which was developed by Wesley is to train the rat to learn to enter a certain open alley which has a certain relationship to the other open ones (e.g., alley no.2), irrespective of its distance

from the entrance, and again the achievement of the rats in this maze was very poor: they learned only to enter the second one.

The results of the two experiments in Chapter IV, each of which employed quite a different training procedure, clearly show that the white rat is able to learn tasks up to six turns, and one S could even reach the criterion of five consecutive correct trials on the seven-turn task, although with very limited success thereafter. The achievements of the white rat in this maze situation are certainly very remarkable compared with the results obtained in the previous studies mentioned above.

Further researches are necessary in order to determine the exact limit of the white rat's capacity in this maze, for one important reason. Of the two experiments that investigated the limit of S's capacity, the second one was supposed to be more adequate than the first because there were fewer control tests to interfere with the training. However, evidence from other experiments suggests that the training schedule employed in Experiment 2 is actually not a very effective one. Therefore, a final conclusion on this matter must be delayed until more effective training is employed.

The results for Ss that were able to master the six-turn task also suggest that the entire course of learning (from the two-turn task to the six-turn task) can be roughly separated into two stages: a stage at which the trial-and-error procedure was very ineffective followed by a stage where the trial-and-error method would be sufficient. For the white rat, the exact task

on which the trial-and-error method would be successful could not be determined, but under the training procedures employed in these two experiments, it happened on the six-turn task. The significance of this feature in comparative studies can only be speculated upon. Presumably it would have some relationship to the intelligence of the animals studied.

The results of Ss that were able to learn at least the four-turn task show that they required fewer trials to reach the criterion of learning on the more advanced tasks, which suggests that they have developed some kind of learning set during the course of training. However, it should be noted that in ordinary learning set studies, the successive problems presented to the animals are generally of comparable difficulty level (see Harlow, 1959, p.492), while in the present study the difficulty of the successive tasks seems to increase as they advanced.

The greater difficulty of the more advanced tasks is shown by the facts that fewer Ss were able to master them; that the efficiency of the performance gradually declined as the tasks advanced; and that the lengths of the errorless runs Ss were able to make on each task gradually shortened (see Chapter IV, Experiment 2). It is quite apparent that one of the pertinent factors that underlies the increasing difficulty of the tasks as they advanced, is the short term memory capacity of the animal studied. In this respect it would appear to have some relationship to the delayed response studies. But the method employed in the present study differs from the delayed response studies in that it minimized the

possible involvement of redintegration (see Munn, 1950, p.278).

NATURE OF THE MAZE BEHAVIOUR

No matter what the limit of the white rat's capacity in this maze situation is, one of the essential problems is how the white rat is able to make the required differential response on the task it is able to master. The experimental setting of this maze situation, which required S to remember or to estimate the merely number of events that follow one another in temporal sequence, makes it quite impossible that S would obtain any differential cues inside or outside the maze for the successful performance. The results of this study also show that S is not obtaining distinctive cues from the noise of the operation of the automatic control circuit, and from the experimenter (Clever Hans type error). The results of other control tests, in which the length of the circular runway and consequently the distance travelled was varied in various manners, show that Ss' successful performance was not based on cues due to distance and cumulative feedback of running activities. Furthermore, it is also shown that the time factor is also not the operative cues for the correct performance. Observation of Ss' behaviour in the maze suggests that their performance in the maze was not so stereotyped as would be expected if they were run on the cues due to time, distance, and cumulative sensory feedback of running activities. It was observed that on the completion of each turn except for the last one, they would usually come to a stop at the entrance for a while

before starting the next turn, and on the last turn they would usually run faster and enter the stem without any delay. On some occasions they could perform some irrelevant acts such as grooming, scratching etc., without affecting the accuracy of performance.

Since all possible cues that might be responsible for the successful performance in this maze situation have been shown to be not essential the view that the white rat is counting the events (e.g., number of turns) seems to have been strengthened. Of course it has to be qualified that it is not counting entirely in the human sense, i.e., to name number. But the tasks used here certainly have some relation to the number capacity of the white rat. It would thus appear that we have here a type of complex behaviour, which may require the postulation of some ideational processes or more specifically some rudimentary processes similar to our counting behaviour.

The results of the present study show for the first time, that the achievement of the white rat in this aspect of behaviour, i.e., to estimate the number of events without help of extraneous cues, is comparable to that of the bird, which has been more extensively studied than the rat.

THE EFFECTIVENESS OF VARIOUS TRAINING PROCEDURES

In the earlier experiment, three Ss were trained to learn the three-turn task without at first mastering the two-turn one. The results of these Ss suggest that mastery of the two-turn task is helpful in the learning of the three-turn one, which led to the decision to

concentrate at this stage of investigation on the studies of learning of the two-turn task. The first experiment regarding the effectiveness of the training procedure was a direct comparison between the guidance and the trial-and-error methods on learning the two-turn task. The results of this experiment clearly show that the trial-and-error method was very ineffective, if not useless, in training the white rat to learn the two-turn task. A certain amount of guidance is necessary. The results show that a fairly large number of guided trials is actually necessary in order to train Ss to learn the task, which makes it possible to use this maze technique to investigate parametrically the effect of guidance on learning. It is also clear from this experiment that one of the main reasons that the previous studies (see Chapter VI) failed to obtain substantial beneficial effects of guidance is that the tasks employed by those studies could be readily learned by the trial-and-error method, which consequently led to the general conclusion that the trial-and-error method is in general the most effective one. The nature of the task is a very important factor.

In the present study, a series of experiments was also carried out to study the comparative effectiveness of various training schedules (i.e., various combinations of guided and free trials) in learning the two-turn task. In two experiments where training schedules with different G/F ratios were compared for effectiveness, the results suggest that the one with the largest G/F ratio ($G/F=2$) is more effective than the others, the ratios of which were either one or smaller than one

(see Chapter VII). This finding contradicts the results of the previous studies, which suggested that to be effective guidance should be given in small amounts. In another two experiments where training schedules with equal G/F ratio ($G/F=1$) were studied, the results were not so conclusive. However, they seem to suggest that the one with shorter consecutive guided and free trial blocks is more effective than the one with longer consecutive trials. For example, if eight guided and eight free trials are to be administered each day, the 4 x (2G 2F) schedule might be more effective than (8G 8F) schedule, at least in terms of the relative rate of learning (see Chapter VIII). In addition, the results of these experiments were taken to indicate that the effectiveness of training schedules cannot be accounted for entirely in terms of the number of the guided or free trials alone, but rather that the interaction of the two is important. Whether or not the guided or free trials would exert any differential effects on learning, and if so what is the nature of these differential effects are interesting problems that may be amenable to experimental study.

One of the dominant aspects of human learning is the process of teaching. When we want to teach children a new word, new skill, etc., we rarely proceed to set up a situation in which 'chance' occurrences of the desired action would be immediately rewarded (a typical animal learning situation). Instead, we usually go forward to teach them how to do it and let them try by themselves, and teach them again if they fail until the response is acquired. It is surprising to note that while one of

the most important aims of animal psychologists, explicitly or implicitly, is to understand the basic mechanisms of human behaviour through the studies of animal behaviour, yet this important problem of the teaching process had not been so much studied as other aspects of behaviour. The results of these experiments have shown that the temporal circular maze used provides comparative psychologists with a useful technique for studying this long neglected problem. Besides the putative value to human psychology, accumulation of evidence on the effectiveness of various training schedules may also contribute to the understanding of comparative learning ability among different species (see Chapter VII), and facilitate applications of this maze in the field of physiological psychology.

APPLICATION OF THE TEMPORAL MAZE IN DRUG STUDIES

Two experiments have been carried out to evaluate the effects of alcohol on the performance of the two-turn task. The effects of alcohol on the performance are found to be (i) depressing the response rate (i.e., the number of total trials made in a certain period decreased), which is in line with the finding of the Skinner box studies (see Chapter IX), and (ii) reducing the efficiency of performance (in terms of the numbers of correct and erroneous trials), which is similar to the findings of Miller and Miles (1936) in an alley maze situation. The familiar alcohol-tolerance effect was also studied. The results suggest that this phenomenon can not be accounted for entirely in terms of physio-biochemical mechanisms; a certain behavioural principle

such as habituation needs to be invoked. More precisely, the results show that there are actually two types of tolerance effect: (i) the gradual decrease of general depressant effect which may be accounted for entirely in terms of physio-biochemical principles, and (ii) gradual improvement of efficiency of performance, which, however, need the postulation of some behavioural or psychological mechanism.

One of the basic requirements for a behavioural technique to be used to assess the actions of drugs is that it can produce a reliable response pattern from which the effects of drugs can be evaluated. The results of several experiments in this study have shown that the temporal circular maze does fulfil this requirement. In addition to this, the maze also possesses some other advantages:

- (1) In this maze situation handling of S during each performance session is not needed, and the maze is adaptable to automatic operations such as delivery of reward and recording of performance.
- (2) The maze technique provides not only the measurement of response rate (i.e., the number of total trials made in a certain period) but also something about the nature of each response, e.g., correct or erroneous response. The advantage of this has been clearly demonstrated in the second experiment of the alcohol study, where if only response rate measure was used, a misleading conclusion might be reached (see Experiment 2, Chapter

IX). Furthermore, distinction can be made between types of errors (overestimation or underestimation). It thus appears that this maze can provide a sensitive assessment of the differential effects of drugs on performance.

- (3) Most important of all, this maze may be useful in studies of the effects of drugs on cognitive or symbolic aspect of behaviour, an area little studied by pharmacologists and psychologists for lack of adequate behavioural tools.

GENERAL CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

Since this study is mainly a pioneer work, the results obtained should be treated as suggestive. More data have to be collected before any final conclusions can be reached, especially on the quantitative aspect of the results. A good example for this is the variability of the results among several experiments on the number of total trials required to reach the criterion of learning the two-turn task. It has been clearly demonstrated in this study that the training schedule is an important variable that affects the rate of learning, but results of the two experiments in Chapter VIII also suggest that there are other still unknown factors that affect the rate of learning.

Taken as a whole, the results of the present study show that the white rat is quite capable of mastering tasks of temporal sequence only, and the successful performance in the temporal circular maze is not based

on any exteroceptive cues, and cues due to distance travelled, cumulative sensory feedback of running activities, and the time factor. They also show that it can be a very useful tool for studying processes of teaching on learning and for assessment of the effects of drugs on performance which may involve symbolic or ideational processes.

Possible applications of the enclosed temporal circular maze in the fields of comparative psychology, learning and drug studies have been suggested and partially investigated. However, it seems to this writer that the most important and urgent problem at this stage of investigations is to continue to study the effectiveness of various training schedules on learning of various tasks, especially the two-turn and the three-turn tasks, and how best the performance can be stabilized. Understanding of this problem will contribute greatly to the understanding of other related problems. One of the basic elements in the advance of knowledge is the development of adequate methods which enable us to investigate some specific questions in a more reliable way. The data of these experiments show that the maze developed in this study may contribute to the understanding of some aspects of behaviour, at least of animals, which have not been properly studied in the past.

APPENDIX Ia

THE CHARACTERS AND SEQUENCE OF TRIALS MADE BY RAT 12 ON
THE THREE TRAINING SESSIONS OF THE SIX-TURN TASK.

First session:

1E(1) 1E(3) 1E(4) 1E(5) 1E(2) 1E(4) 2E(1) 1E(4)
 1E(5) 1E(1) 2E(5) 2C 3E(5) 1E(1) 1C 1E(5) 1C 1E(5)
 3C 1E(5) 2C 1E(5) 1C 2E(5) 2C 1E(5) 5C 1E(5) 4C
 1E(5) 4C 1E(5) 2C 2E(5) 9C 3E(5) 2C 1E(5) 2C 1E(5)
 2C 1E(5) 2C 1E(3)

Second session:

1E(1) 1E(3) 8E(1) 2E(3) 2E(4) 1E(1) 1E(5) 3E(1)
 1E(4) 1E(5)...(sat at the food cup for at least
 16 minutes).

Third session:

1E(4) 1E(5) 1E(4) 1C 1E(1) 2E(5) 1C 1E(5) 6C
 1E(5) 1C 1E(7) 3C 2E(5) 5C 1E(7) 1C 2E(7) 1E(4)
 1E(5) 1C 1E(7) 1C 1E(5) 1E(1) 2C 1E(5) 2E(7) 3C
 1E(5) 6C 2E(7) 2C 1E(5) 3C 1E(7) 3C 2E(5) 1C
1E(7)

(underlined seven-turn errors were rewarded to
 prevent possible disorganization of behaviour
 which might be triggered by too many non-rewarded
 trials at this stage of training).

APPENDIX 1b

THE CHARACTERS AND SEQUENCE OF TRIALS MADE BY RAT 15 ON
THE FIRST TRAINING SESSION OF THE SIX-TURN TASK, AND BY
RAT 20 ON THE FIRST TRAINING SESSION OF THE SIX-TURN
AND THE SEVEN-TURN TASK

Rat 15 (six-turn):

1E(2) 4E(4) 5E(5) 1E(1) 1E(5) 1C 4E(5) 1E(1) 1E(3)
2E(5) 1C 1E(5) 1C 1E(5) 4C 1E(5) 4C 1E(5) 1E(3)
2E(5) 1C 1E(5) 1C 1E(2) 1E(5) 4C 2E(5) 1C 2E(5)
1E(2) 7C 3E(5) 1E(2) 1E(5) 1C 1E(5) 4C 1E(5) 1C
1E(1) 2E(5) 1E(1)

Rat 20

Six-turn:

1C 1E(5) 2E(4) 2E(5) 6C (circuitry was put out of
action) 1E(4) 1E(5) 2C 1E(5) 4C 1E(5) (circuitry
in normal function again) 1E(5) 1C 1E(5) 1C 1E(5)
2C 1E(3) 4C 1E(5) 1C 1E(5) 1E(4) 2C 1E(5) 1C 1E(5)
4C 1E(5) 2C 1E(7) 3E(5) 1E(3) 3C 1E(5) 1E(3) 1E(1)
2C 1E(7) 1C 1E(4) 3C 1E(5)

Seven-turn:

1E(1) 1E(4) 1E(6) 2E(5) 1E(6) 2E(5) 2E(6) 1E(1)
2E(6) 1C 2E(6) 5C 1E(1) 2E(6) 1E(2) 1C 1E(6) 1E(1)
4C 1E(6) 2E(1) 1C 15E(1)

APPENDIX IIa

THE CHARACTERS AND SEQUENCE OF TRIALS MADE ON THE CRITICAL TEST STAGES OF THE CONTROL TEST 3 FOR RATS 2, 3, 5, 8, (ON THE TWO-TURN TASK), AND 12 (ON THE FOUR- AND THE FIVE-TURN TASKS). ABBREVIATIONS USED FOR THE PRESENTATION OF THE RESULTS ARE: C FOR CORRECT; E(1), E(2), E(3), ETC. FOR ONE-TURN ERRORS, TWO-TURN ERRORS, THREE-TURN ERRORS, ETC.; L FOR LARGE RUNWAY; S FOR SMALL RUNWAY; THUS 1C(LL) 1E(2)(LL) 1E(2)(SS) MEANS ONE CORRECT TRIAL IN WHICH ALL THE THREE TURNS WERE RUN IN THE LARGE RUNWAY FOLLOWED BY ONE TWO-TURN ERROR IN WHICH ALL THE TWO TURNS WERE RUN IN THE LARGE RUNWAY FOLLOWED BY ONE TWO-TURN ERROR IN WHICH ALL THE TWO TURNS WERE RUN IN THE SMALL RUNWAY AND SO ON.

Rat 2 (three-turn task: stage 3):

1C(LL) 1E(2)(LL) 1E(2)(SS) 1C(SLL) 1E(2)(LS)
 1C(LL) 1C(LSS) 1E(2)(SS) 1C(SLL) 1E(2)(LL)
 1E(1)(L) 1C(SSS) 1C(LSL) 1C(SSS) 1C(SSL) 1C(SLL)
 1E(2)(LS) 1C(SSS) 1C(SLS) 1C(LSL) 1E(2)(LS)
 1E(4)(SLSS) 1C(LLS) 1E(2)(LL) 1C(LLS) 1C(SSL)
 1C(LSS) 1C(SSS) 1C(LL) 1C(LSL) 1C(LSL) 1C(LLS)
 1C(SLS) 1C(LSS) 1C(SSL) 1C(LL) 1C(LSS) 1C(SSS)
 1C(LSS) 1C(LL) 1C(SLL) 1E(4)(LSLL) 1E(1)(L)
 1C(SSL) 1C(LL) 1C(LLS) 1C(SSS) 1C(SSL) 1E(2)(LL)
 1C(LSL) 1C(LSS) 1C(LL) 1C(LSS) 1C(LSS) 1C(SLL)
 1C(SLL) 1E(2)(SL) 1C(LSL) 1C(SLS) 1C(LSL) 1E(2)(SS)
 1C(LSL) 1C(LSL) 1C(LSS) 1C(LL) 1C(LLS) 1C(SSS)
 1C(LLS) 1C(SSS) 1C(LSS) 1C(SLS) 1C(SSL) 1E(2)(SL)
 1C(LLS) 1E(4)(SLLL) 1E(2)(SL) 1C(LL) 1C(SSS)
 2E(2)(LL) 1C(LSL) 1C(SSS) 1C(LL) 1C(SSL) 1C(SLS)
 1E(2)(LS) 1C(SSS) 1C(SLS) 1C(SLS) 1C(SSS) 1C(SSL)
 1C(LLS) 1E(5)(LLLL) 1C(LL) 1C(LSS) 1C(SLL)
 1C(SSL) 1C(LSS) 1E(2)(LL) 1C(LSS) 1C(SLL)

1C(SSS) 1C(LLS) 1C(SSS) 1C(LSS) 1C(LLL) 1C(SLS)
 1C(SSL) 1C(SSS) 1E(2)(LL)

Rat 3 (three-turn task; stage 2):

3C(LLL) 1E(2)(SS) 1C(LLL) 1C(SSS) 1C(LLL) 1C(SSS)
 1C(LLL) 1E(2)(SS) 1C(LLL) 1E(4)(LLLL) 1C(LLL)
 1C(SSS) 2C(LLL) 1C(SSS) 1C(LLL) 1C(SSS) 1C(LLL)
 1E(4)(LLLL) 3C(LLL) 2C(SSS) 1C(LLL) 1C(SSS) 1C(LLL)
 3C(SSS) 1C(LLL) 1C(SSS) 1C(LLL) 1C(SSS) 1E(2)(SS)
 3C(LLL) 2C(SSS) 1C(LLL) 1C(SSS) 1E(2)(SS) 1C(LLL)
 2E(2)(LL) 2C(LLL) 2C(SSS) 1C(LLL) 1E(2)(LL) 3C(LLL)
 3C(SSS) 5C(LLL) 3C(SSS) 1E(4)(LLLL) 2C(SSS) 1C(LLL)

Rat 5 (three-turn task; stage 3):

1C(LLL) 1C(SSL) 1C(SSS) 1E(2)(SL) 1C(SLS) 1C(SLL)
 1C(SSS) 1C(LLS) 1E(2)(LL) 1C(LLS) 1C(LSL) 1C(LSS)
 1C(LSL) 1C(LSL) 1E(2)(LS) 1C(SSS) 1C(SLS) 1C(LLL)
 1C(SSL) 1C(LLL) 1C(LLS) 1C(SLL) 1E(2)(SS) 1C(SSL)
 1C(LLL) 1C(SLS) 1C(SSL) 1E(2)(LS) 2C(SLL) 1C(SLS)
 1E(4)(SLSS) 1C(SSS) 1C(LLS) 1C(LSL) 1C(LSL) 1C(SLS)
 1C(LLS) 1E(2)(LS) 1C(SSS)

Rat 8 (three-turn task; stage 3):

1C(SLL) 1C(SSS) 1C(LLS) 1C(LLL) 1C(SLL) 1C(SSL)
 1C(SLL) 1E(2)(SS) 1C(LLS) 1E(2)(LL) 1C(LLL) 1C(SSS)
 1C(LLL) 1C(SLS) 1C(LSL) 1C(SLS) 1E(2)(LL) 1C(SSL)
 1C(LSS) 1C(LLL) 1C(LSL) 1C(SLS) 1C(LSS) 1C(SLL)
 1C(LSS) 1C(LSL) 1C(LLL) 1C(SSS) 1C(SLL) 1C(SSL)
 1C(LSS) 1C(LLL) 1C(SLL) 1E(4)(SSLL) 1C(LLL)
 1C(SSS) 1C(LSL) 1C(LLS) 1E(2)(SS) 1E(2)(LL)
 1C(LLS) 1C(SSS) 1C(LSL) 1C(SLL) 1C(LSS) 1C(SSS)
 1C(LLL) 1C(LSL) 1C(LSS)

Rat 12 (four-turn task; stage 3):

First session:

1C(LLLL) 1C(SSSS) 1C(SLLL) 1C(LLLL) 1C(LSLL)
 1C(LLSS) 1E(3)(SSS) 1E(3)(LLL) 1E(3)(SLS) 1E(1)(S)
 1C(LLLL) 1E(5)(SSLLL) 1E(3)(LLS) 1E(3)(LSS)
 1E(5)(LSLLL) 1C(SSLL) 1E(3)(SLS) 1E(5)(SLSSS)
 1C(SSSS) 1E(3)(LLL) 1C(LSLL) 1E(1)(L) 1C(SLSS)
 1E(5)(LLLLL) 1C(SLLL) 2C(SSSS)

Second session:

1C(SSSL) 1C(SLLL) 1C(SSLL) 1C(SSSL) 1C(LSLL)
 1C(LSLL) 1C(SLLL) 2E(3)(LLL) 1E(2)(LL) 1E(3)(LSS)
 1C(SLLS) 1C(LSSS) 1C(LSLL) 1C(SSSL) 1C(LLSS)
 1E(3)(LSL) 1C(SLSL) (72per cent correct)

Third session:

1C(LSLL) 1C(SLSL) 1C(SLLL) 1C(SLSS) 1C(LSLL)
 1C(LSSL) 1C(LLLL) 1C(SSLS) 1C(SSLL) 1C(LLLS)
 1C(LLLS) 1E(3)(LLS) 1C(SLLS) 1C(SSLS) 1C(SSSS)
 1C(LLLL) 1C(SSSL) 1C(LLLL) 1C(SLSS) 1C(LSLL)
 1C(SLLS) 1C(LLLS) 1C(SLSL) 1C(SLSS) 1C(SLLS)
 1E(3)(SSS) 1C(SLLS) 1C(LSLS) 1C(LLSS) 1E(2)(LS)
 1C(SSSS) 1C(LSLL) 1C(LSSL) 1C(SSLS) 1C(SLLL)
 (91per cent correct)

Sixth session:

1C(LSSS) 1E(3)(SLL) 1E(3)(LSS) 1E(5)(SLSSS)
 1E(3)(SLL) 1C(LLLL) 1C(SSSL) 1C(LLLL) 1C(LLSL)
 1C(SSLS) 1C(LLSL) 1C(LSLS) 1C(SSSL) 1E(5)(SLLLL)
 1C(SLSL) 1E(5)(LSSSS) 1C(SLLL) 1E(5)(SSSLL),
 1C(LLLL) 1E(5)(SLSLL) 1E(5)(SSSSS) 1C(LLLL)
 1C(SSSS) 1C(SSSS) 1C(LLLL) 1C(LSSL) 1C(LLSL)

1C(SSLL) 1C(LLLL) 1C(SSLS) 1C(SLSS) 1C(SLLL)
 1C(LSSS) 1C(SSLL) 1C(LLSL) 1C(LLLL) 1C(SSSS)
 1C(SLLS) 1C(SLLS) 1C(SSSS) 1C(SSSL) 1C(LLLL)
 1C(SLLL) 1C(LLSL) 1C(SSSS) 1C(LSSL) 1C(LLSS)
 1E(3)(SLL) 1C(SSSS) 1C(LLLL) 3C(SSSS) 1E(3)(LLL)
 1C(LLLL) 2C(SSSS) 3C(LLLL) 1C(SSSS)
 (82per cent correct)

Rat 12 (five-turn task; stage 3):

1C(SSLSS) 1E(4)(SLSL) 1E(4)(LSSS) 1E(4)(LSLS)
 1E(4)(LSLL) 1E(4)(LSLL) 1C(SSSSS) 1E(4)(LLLL)
 1C(SSSSS) 1C(LLLLL) 1C(LSSLL) 1C(SSLSS) 1C(LLSLs)
 1C(SLSLS) 1C(SSLSL) 1C(LLSSL) 1C(LLLSL) 1C(LLSSS)
 1C(LSSSL) 1C(SLLLL) 1C(LLSSS) 1C(SLLSS) 1C(LLSSS)
 1C(LLLLS) 1C(SSLLS) 1C(SLLLS) 1C(SLSSL) 1C(LLLLL)
 1C(SLLSL) 1E(4)(SLSL) 1C(SLLSL) 1C(LLSSL) 1C(SLSSL)
 1C(LSSSL) 1C(LSSSS) 1C(SLLSL) 1E(4)(SLLS)
 1E(6)(SLLSSS) 1C(SLSLL) 1C(SLLSS) 1C(SSSLL)
 1C(LLSSS) 1C(SSSSS) 1E(4)(LSSL) 1C(LLLLL) 1C(SSSSS)
 1C(LLLSL) 1E(4)(SSSL) 1C(LSLLL) 1C(LLSSL) 1C(SLMLS)
 1C(LSSSS) 1C(SLLSL) 1C(SLLSL) 1C(SLSSL) 1C(LLSLs)
 1C(LSLSL) 1C(SLSLL) 1C(SLSSS) 1E(4)(SSSL) 1C(LLLLL)
 1C(SSSSS) 1C(LLSSL) 1E(4)(LLSL)

APPENDIX IIb

PERCENTAGE (AND RATIO) OF CORRECT TRIALS MADE IN THE THREE CONTROL MAZES
(5 IN., 8.5 IN., AND 2.5 IN.) ON THE SECOND CONTROL SESSION OF CONTROL
TEST 4a.

Maze situation	Subject				
	14	15	19	20	21
5 in. control: first 30 trials remaining 30 trials	80 (24/30) -	80 (24/30) -	27 (8/30) 100 (20/20)	80 (24/30) -	73 (22/30) -
8.5 in. control: first 30 trials remaining 30 trials	60 (18/30) 60 (6/10)	53 (16/30) 70 (7/10)	47 (14/30) 72 (18/25)	67 (20/30) 70 (7/10)	83 (25/30) -
2.5 in. control: first 30 trials remaining 30 trials	70 (21/30) -	3 (1/30) 3 (1/30)	70 (21/30) 90 (9/10)	90 (27/30) -	63 (19/30) -

APPENDIX IIIa

NUMBERS OF CORRECT TRIALS MADE IN 50 FREE TRIALS FOR RATS
24, 25, 26, AND 27 ON FIVE ALCOHOL SESSIONS OF TWO
CONCENTRATIONS

Session No.	Rat 24		Rat 25		Rat 26		Rat 27	
	10%	15%	10%	15%	10%	15%	10%	15%
1	49	0*	0*	0*	50	43	39	0*
2	47	38	49	42	48	48	46	0*
3	45	48	46	46	49	41	45	46
4	49	44	50	47	47	46	44	45
5	46	43	45	46	46	39	48	46

* sessions were discontinued 45 minutes after
the sessions started.

APPENDIX IIb

NUMBERS OF CORRECT TRIALS MADE IN SUCCESSIVE BLOCKS OF TEN TRIALS ON ALCOHOL SESSIONS FOR RATS 24, 25, 26, AND 27.

Subject	Successive blocks of ten trials									
	1st		2nd		3rd		4th		5th	
	10%	15%	10%	15%	10%	15%	10%	15%	10%	15%
24	Mdn	8	4	10	9	10	10	9	10	10
	Range	7-9	0-8	7-10	0-10	0	0-10	0-10	0	0-10
25	Mdn	8	6	10	9	10	9	10	10	10
	Range	0-10	0-8	0-10	0-10	0-10	0-10	0-10	0-10	0-10
26	Mdn	9	6	10	10	10	10	9	10	9
	Range	6-10	2-9	9-10	8-10	0	6-10	0	8-10	0
27	Mdn	7	7	10	9	10	7	10	9	9
	Range	1-9	0-9	8-10	0-10	0	0-10	7-10	0-10	8-10

some of the lower values of the range for rats 24, 25, and 27 were based on the trials they made on the unfinished sessions.

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