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UNIVERSITY OF CINCINNATI

June 1933

I hereby recommend that the thesis prepared under my supervision by Wilder Rosbert Reynolds

entitled "The Effect of Tobacco Smoke on the Growth and Learning Behavior of the Albino Rat and Its Progeny"

be accepted as fulfilling this part of the requirements for the degree of ______

Approved by:

L. A. Pechstein, Adviser

Gordon Hendrickson

C. A. Gregory

Form 668—G. S. and Ed.—1M—7-31

THE EFFECT OF TOBACCO SMOKE ON THE GROWTH AND LEARNING BEHAVIOR OF THE ALBINO RAT AND ITS PROGENY

A dissertation submitted to

The Graduate Faculty of the Teachers College
of the University of Cincinnati

in partial fulfillment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY IN EDUCATION

1935

by

Wilder Rosbert Reynolds
A.B. McPherson College 1919
A.M. University of Rochester 1922

ACKNOWLEDGMENT

The writer desires to express his gratitude to those who have assisted in the carrying out of this experiment; particularly to Dean L.A. Pechstein, his adviser, who has for the second time in eleven years laid upon the writer a deep obligation of gratitude by his stimulating guidance and counsel; to Drs. Gordon Hendrickson and C.A. Gregory, members of the advisory committee, for valuable advice and criticism of the manuscript; to Dr. Charles K. Weichert, Assistant Professor of Zoology, for advice upon the handling and care of the animal subjects; to Dr. D.E. Jackson, Professor of Pharmacology, for suggestions concerning the experimental set-up and interpretation of the results; to Dr. Ada Hart Arlitt, Professor of Child Care and Training, for advice and suggestions growing out of her own doctoral dissertation; and to Beulah Allen Reynolds, whose constant and devoted cooperation greatly lightened a heavy load.

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CHAPTER I

NATURE OF THE PROBLEM

The tobacco problem is a subject of very general interest upon which many distinguished persons hold widely divergent views. Some of the literature appearing upon the subject gives very damaging evidence concerning these effects. Some of the medical literature dealing with the problem purports to trace the effects of nicotinism in the pathology of nearly every organ and process of the body. In view of the widespread popularization of the fad of smoking, especially among the younger generation of both sexes, that fact may hold consequences approaching the dimensions of a major catastrophe for society, if many of the allegations are sustained.

The potential menace of the situation has been clearly recognized by medical men, educators, industrial leaders, and social and religious workers throughout the world. A great mass of clinical and scientific data is available dealing with many phases of the subject and more is being produced steadily. Much of it, however, is inconclusive and oftentimes sharply contradictory; but such a condition is not strange in view of the many difficulties involved in an adequate study of the problem.

Especially is this true with regard to those studies and experiments which deal with human subjects. The conditions for scientific experimentation are so difficult and the unknown factors involved and operating are so complex that they make many of the conclusions uncertain and the positions assumed vulnerable. It is generally recognized that much patient experimentation and extensive investigation will yet be needed before final answers can be given to many of the vital questions involved in the whole tobacco problem.

Previous Investigations

The Committee to Study the Tobacco Problem has sponsored a great deal of work dealing with the problem in recent years. Its roster contains an imposing list of names of fifty-two eminent physicians, college presidents, university professors, physical directors, religious leaders, character building organization executives, industrial leaders, economists, and editors. Some of the leading investigations have been carried out under its auspices.

One of the excellent volumes published under its direction is a succinct summary of the literature which has appeared upon the subject in many countries and languages (23). It contains also an annotated bibliography of practically all the experimental and clinical data produced before 1927. There are over 875 titles in this bibliography the most of which are probably of a medical and clinical nature.

The mass of experimental literature dealing with the subject may be classified according to three major types, (1) physiological, (2) psychological and (3) statistical. The physiological list comprises by far the largest part of all the studies. This includes all the clinical and medical data and the various studies that have been carried out in the field of animal experimentation.

The psychological group is very limited in its scope. In nearly all cases the subjects have been college men, and the aim has been to discover the immediate effects of smoking upon various mental processes. Representative of this group are the studies by Hull (12), Bates (2), Baumberger and Martin (3), and Carver (6).

By far the most elaborate of these studies is the one carried out by Hull, assisted by seven staff workers in the University of Wisconsin. But the difficulty of getting positive, definitely assured results from such studies is evidenced by the fact that he states at the close of his monograph that it would be very risky to draw any conclusions whatsoever regarding the ultimate effects of smoking from their experiment.

The statistical method attempts to test the effects of long continued smoking upon the mental processes. Representative of this group are the studies by Meylan (19) and Earp (8). A favorite method here has been to compare the college marks of a group of smokers with those of non-smokers over a period of years. But the difficulty in such studies is one of control. Hull shows that by partialling out the factors of athletics and fraternities the difference indicated in Meylan's study could be reduced by half. What other factors might have been playing a potent part in producing the differences is of course impossible of determination. It is clearly impossible to control a score of extraneous factors in such studies, any of which might be sufficient to produce significant variations.

The evidence concerning the psychological effects of tobacco smoke as indicated in the experimental literature is by no means conclusive. Some of the literature marks the harmful effects upon scholarship; yet much of it points to negative, and some to beneficial, results of smoking for scholarship. It is very doubtful, notwithstanding a rather prodigious mass of scientific data, if very much more is known today about the psychological effects of smoking than was known twenty-five years ago.

In the physiological field much of the data has the merit of being at least tangible. Medical and clinical data shows very definite deleterious effects of nicotinism on the various organs and functions. But of course it deals with only pathological, and perhaps that means exceptional, cases. How universally these maladies accompany tobacco addiction is wholly unknown. Such studies as have attempted to get at the more universal effects of smoking upon the purely physical functions have been subjected to the same difficulties of control that the psychologists have encountered.

It is unquestionably in the field of animal experimentation that many controverted points must be largely decided. Even then it cannot be maintained that the nicotine affects humans and animals alike; in fact there is practical certainty that it does not. But on the basis of the grosser trends established by it, a strong hypothetical case may be positted for humans. At least it may indicate certain areas that ought to be investigated, and perhaps it may determine valid methods to be used in such investigations.

Considerable work has already been done in this field. A survey of the titles in the annotated bibliography by Schrumpf-Pierron mentioned above reveals the fact that experiments have been conducted with rabbits, rats, guinea pigs, mice, frogs, dogs, birds, insects and plants as subjects. Among those the following may be singled out as of most interest for the present study. Glogau produced acute nicotine poisoning of the inner ear in pigeons and guinea pigs; Zebrowski found that animals inhaling smoke sustained injury to the kidneys; Depierris noted lessening of generative capacity of a cock and rabbit under tobacco smoke; Wright noted sclerosis of testicles in the guinea pig; and five Frenchmen, Richon, Perrin, Fleig, Guillan and Gy noticed retardation of growth of young animals resulting from tobacco smoke.

Of more importance for this research are the studies of Nice (20) and Field (9). Nice studied the comparative effects of alcohol, nicotine, tobacco smoke, and caffeine on the growth of white mice, and later the effects of nicotine on their activity. The results for nicotine, which was given to them in their drinking water, were practically negative, whereas those that were fumed had more young than the others but a much larger percent of them died. He also reports the work of Flieg, a Frenchman, who subjected guinea pigs to heavy inhalations of tobacco smoke, to injections of smoke or nicotine and obtained abortions, still births, weak and stunted young.

Field attempted to stimulate human smoking conditions by contriving a revolving cage into which smoke was introduced in puffs. She found that tobacco smoke served as a decided stimulant and that the effects were apparent for a period varying from fifteen minutes to one and one-half hours after smoking.

It is noteworthy that, in the field of animal experimentation, apparently no one has studied the tobacco problem from the vantage point of the psychologist. Experimenters have discovered with some degree of unanimity that tobacco smoke and nicotine variously administered to produce certain physiological effects, but no previous research has attempted to determine the effects upon the intelligent behavior of animals. Neither has there been anything like an extended study of the hereditary effects of tobacco smoke. Towards these major problems the present research has been directed. Incidental to them have been various other closely related problems some of which have received rather detailed treatment in the body of the paper.

The present, indefinite state of the problem for all interested agencies is correctly summarized in the words of a medical authority.

> The general conclusion of medical knowledge regarding the effect of tobacco upon the animal organism is that data is still incomplete for a scientific point of view.
> Further controlled clinical and laboratory studies seem desirable in order to attain more precise knowledge regarding the ultimate effect .... of tobacco .... (23:54,55).

The Aim of the Investigation

It was the purpose of the research to determine certain physiological and psychological effects of tobacco smoke upon white rats. On the physical side this included the following: (1) what effect the inhalation of tobacco smoke has upon the fertility of the parent stock and the viability of their young; (2) what effect it has upon the rate of growth of young rats and how this affects the ultimate body size; and (3) what hereditary effects are produced by it. On the learning side it sought answers to the following problems: (1) what effects smoking has upon the learning behavior of rats; (2) what differential effects may result from varied amounts of smoking; (3) what sex-differences are produced by it; and (4) to what extent these effects are transmitted to progeny.

CHAPTER II

EXPERIMENTAL PROCEDURE

Selection and Groupings

The experiment was conducted on the basis of equivalent groupings of animal subjects. The foundation stock, Wistar Institute rats of excellent quality, was secured from the Department of Zoology of the University of Cincinnati. This consisted of six females and two males representing three litters, and these were used to start both the control and the experimental lines. The rats which constituted the original stock were very closely related, their lines having been closely inbred for generations. The hereditary factors were therefore as nearly identical for all groups as could be well achieved. The variable factors such as feeding, housing, training, etc., were rigidly controlled to make them as nearly equivalent for the various groups as possible. It can be said that all things were equal to a very high degree for the various groups except the experimental factor of tobacco smoke.

The experiment was begun early in 1932; in fact, a preliminary experiment incident to it was begun December 24, 1931. But from early in February to January 23, 1933, the experimental stock was under the daily care and observation of the experimenter.

The first litters of the foundation stock, consisting of thirty-six surviving young, were designated as the first generation controls or the CI group. Six females and one male were kept as breeders and observed for nearly eight months. Those with learning records nearest the average of learning time for the entire group were selected.

After the weaning of these first litters, the original stock was subjected to the smoking process daily for a period of fourteen days. At the end of that time they were put into the breeding pen. The smoking was continued through the gestation period and during the time of suckling. Two of the females were destroyed because of inner ear infection and other causes, but the young of the others, consisting of thirty-seven survivors, were used to start the experimental line. Since the parent stock had been fumed for a period of six or eight weeks before these were weaned, this group was labelled the second generation experimentals or the EII group. Six females and two males with learning records nearest the mean learning time of the entire group were selected as breeders. These were kept and observed for six months.

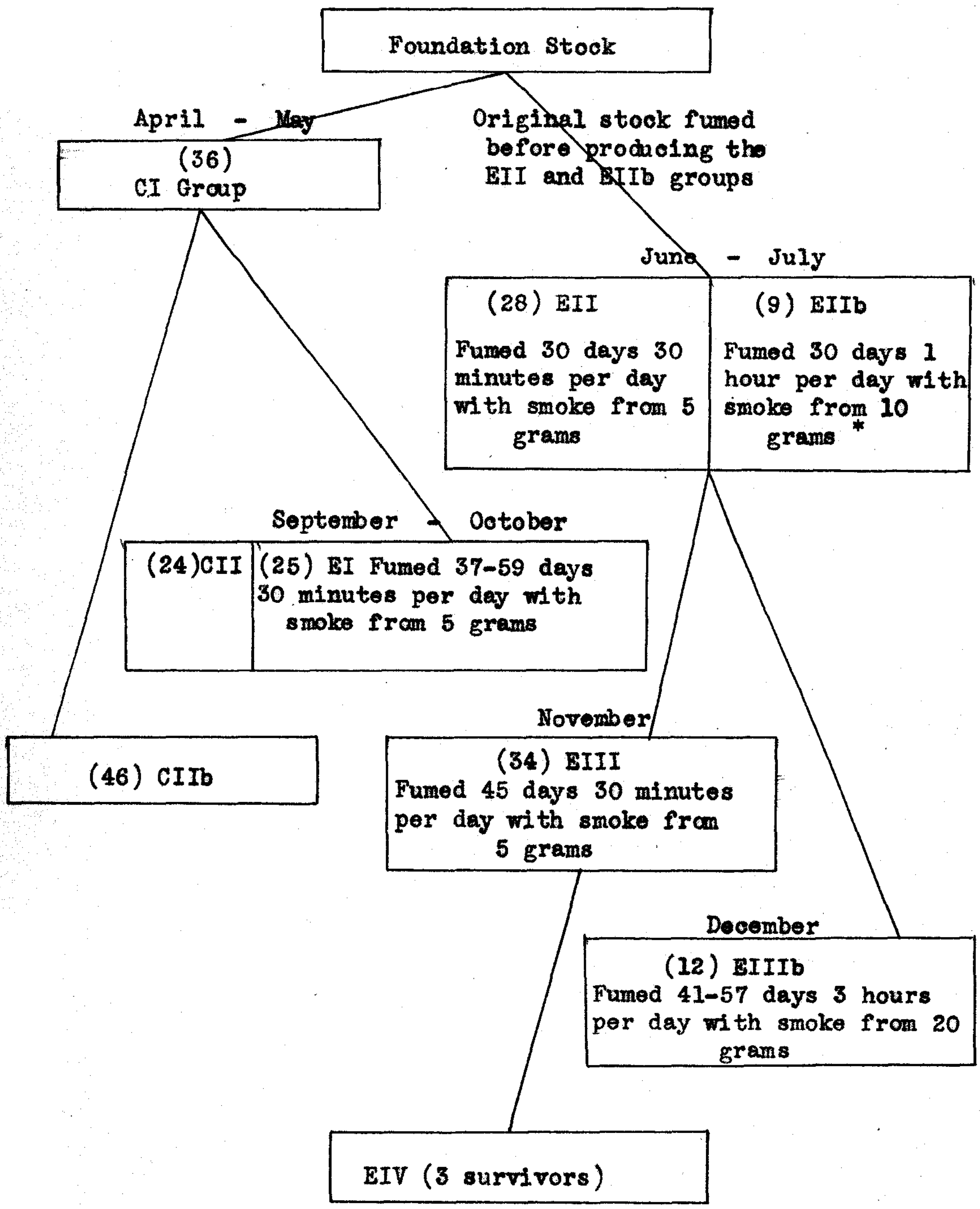
The first litters of the control group numbered forty-nine surviving young. These six litters were divided as nearly as possible into two equal groups, each litter being divided equally on the basis of sex and weight. One of these groups was fumed in the regular way and the other served as controls. These two groups were designated respectively as the first generation experimentals (EI group) and the second generation controls (CII group). It was not deemed necessary to retain any of these as breeders, since the records for subsequent generations were being established by other groups of the same blood strain. See figure 1 for a schematic representation of the general breeding plan.

The first litters of the experimental (EII) group totalled sixty-six young born in six litters. One litter of ten survived only a day or two. A wild rat succeeded in getting into the room where they were kept and under the wire netting bottom of cage in which many young were placed. About fifteen of these were so maimed by it that it was necessary to destroy them. Others died so that the group which composed the third generation of experimentals (EIII group) was reduced to thirty-four. Eight females and three males, selected from this group at random, were retained as breeders. In addition to the thirty-four was a group of twelve selected at random from the second litters of the parent stock of this third generation of experimentals. These were fumed for a much longer period of time each day and were designated as third generation experimentals B (EIIIb group).

The selected breeders from the EIII group were placed in the breeding pen at eleven or twelve weeks of age as was the custom with all the groups. Five of the eight females littered, bearing a total of seventeen young. All of these except three were either still-born or survived but a day or two. The smoking was then discontinued and the females were replaced in the breeding pen. They were kept thus until they were twenty-two weeks of age, but no more litters were born. The group was then discarded and the experiment brought to a close.

Handling and Care

All rats were fed a specially prepared mash, the formula for



* Fumed 60 days in all, during first 30 days 30 minutes per day with smoke from 5 grams.

Fig. 1. Schematic representation of the breeding plan showing line development and group relationships. Months indicate the time of training.

which was provided by the Department of Zoology.* This with fresh water was kept before them at all times. Occasionally they were given lettuce leaves to eat.

The young were weighed weekly or bi-weekly as near the same hour of the day as possible. Entire litter groups were weighed simultaneously on ordinary dial scales. It was impossible, on account of the great activity of such groups, to determine the correct weight within less than one-third or one-fourth of an ounce, but such errors tended to be compensating. All weights were computed and recorded in terms of grams.

The rats were kept in all-wire cages which were maintained in a sanitary condition at all times. The first three groups were reared in the laboratory, but with the onset of the hot weather of the summer, the breeding stock was removed to a room in a vacant apartment where it was cooler. This room was adequately heated, and here the later groups (CII, EI, EIII, EIIIb and EIV) were reared. In both places the stock was maintained in a very thrifty condition. In more than a year's time no epidemic or malady of any sort developed.

Four days before the tuition began the rats were taken to the laboratory. The question should be raised as to the effects of this change upon their learning efforts. Might not this introduce a disturbing factor that would greatly influence the learning records? Tryon's (26:318) experiments tend to show that environmental interpolations such as seasonal changes, variable breeding conditions,

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* The mixture included corn meal, rolled oats, whole wheat flour, powdered whole milk, dried meat scraps, alfalfa meal, salt, and $CaCO_3$.

removal to new quarters, etc., have but little effect if any upon learning ability. That conclusion, in the main, may be substantiated by this study.

There were, however, other factors in the situation that did seem to materially affect the records. The rats which were reared in the laboratory were rarely disturbed except by the daily visits of the experimenter in looking after their care. The result was that they tended to be somewhat timid and easily frightened. Avoiding reactions and other emotional disturbances not infrequently characterized their behavior in the maze learning situation with the result that their learning records were correspondingly affected.

On the other hand, those that were reared in the vacant apartment room were subjected to a variety of experiences. For one thing the experimenter and members of his family spent much more time working with them and studying them than was the case with the laboratory groups. These were frequently handled and petted and the result was that they became as gentle as kittens. The experience of being put into boxes and transported by automobile to the laboratory apparently provided them with no very novel or disturbing situation. And in their maze learning they were wholly unafraid and lacking in timidity. The result was that both controls and experimentals scored uniformly higher records than did those reared in the laboratory. No doubt it would be wrong to aver that the varied experiences made these brighter than the others, yet it certainly is true that they served to break down the natural hindrances to maximum performance in the maze learning situation. The conclusion is irresistible that any group comparisons for rats in such a situation which are not based on equality with respect to this one factor of domesticity are unreliable to some degree.

Apparatus for Administering the Smoke

The smoker (Fig. 2) was a tight box 21 x 21 x 26 inches with a glass door in the front. The door was weather-stripped making the box tight enough to hold the tobacco fumes for several minutes after the tobacco had burned out. Fresh air entered the box with the smoke through the bottom only. The result was that the interior of the box contained a very heavily smoke saturated volume of air. All-wire cages 17 x 20 x 5½ inches held the subjects and these could be placed in the smoker at various levels. The usual procedure was to place them in the upper half of the box where the smoke was the most dense.

A popular brand of smoking tobacco was used. It was burned in a small burner which was placed inside a six inch pipe ten inches long, fastened into the center of the bottom of the box. The standard amount of tobacco burned was five grams, and the subjects were fumed for a period of thirty minutes per day six days a week.

From former analyses of tobacco smoke that have been made (23:10f), the total content of poisonous substances contained in the volume of smoke produced from five grams of tobacco and inhaled each day by the subjects was as follows:

1. Pyridine, Thiotetrapyridine, and Isodipyridine, 4.5 to 6 mgms.
2. Nicotine, 10 to 12 mgms.

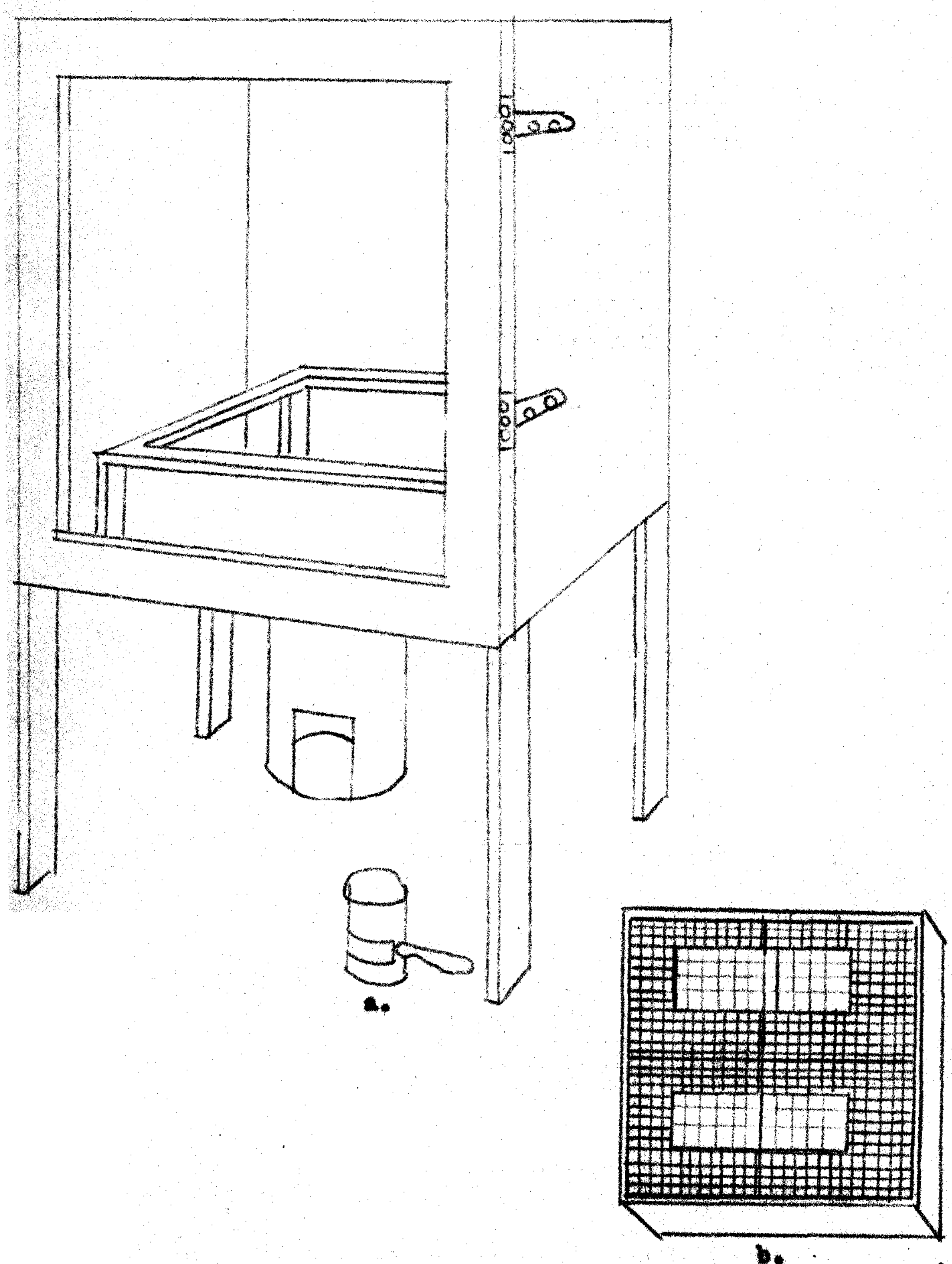

Fig. 2. The smoker
a. The burner
b. The cage

5. Carbon monoxide, 410 c.c. This gas is one of the most harmful elements of tobacco smoke.

Other substances present in varying amounts are Prussic Acid, Ammonia, Formaldehyde, Pyrolin, and Collidine.

The Maze

The maze pattern was designed solely with a view to making it long and difficult. A choice presented itself between a simple maze in which the time and errors in the initial trials would be uncontrolled, or a hard maze with a measure of control during the first trials. The latter was selected as being a much more effective method of bringing out any significant differences which might be produced in the rats by the experimental factor of tobacco smoke. A cut of it appears in figure 3 below.

The maze pattern decided upon was readily set up in a laboratory maze which had been ingeniously devised to make it readily adaptable to a great variety of maze patterns. This consisted of a box forty-eight inches square by five inches deep and cross-grooved at intervals of four inches. The box itself was made of $1\frac{1}{4}$ inch oak stock, stained without and painted black inside. Panels made of heavy galvanized iron of various lengths could be inserted into the grooves to make nearly any desirable pattern. The panels were also painted black.

The true path-way was 368 inches in total length. There were sixteen cul de sacs, fourteen of which opened directly on the true path-way. The cul de sacs totalled an additional 190 inches.

The food box was eight inches square located in the center of the maze. A close fitting frame covered with one-half inch mesh wire netting covered the maze. A trap door in the netting at "e" served as the place of ingress. A hinged door could be closed down over the food box, but this was always left open. A four inch panel was slipped into the groove at the entrance to the food box after the rat had entered.

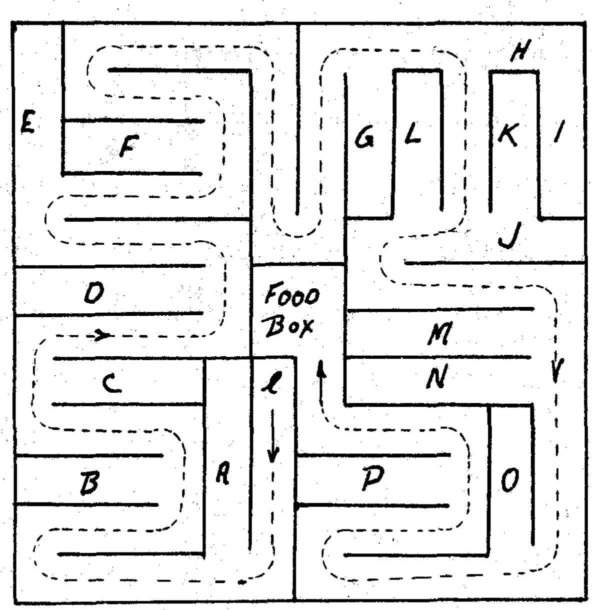

Fig. 3. The Maze

The maze was placed in an alcove which was located in the northeast corner of the commodious laboratory. This alcove was about 12' x 14' with a large northern window exposure. The shade to this window was kept drawn, and a ceiling light centered about ten feet above the maze was always turned on during the practice periods. Shades at the windows on the south side of the larger room were adjusted according to the conditions of the day. Thus the maze was kept free from shadows, and the intensity of the illumination was kept fairly constant. The maze was set on the floor, and the experimenter sat in a chair directly in front of the point of entrance. These conditions were constant for all groups of rats.

Criteria of Learning

The three factors of learning time,* trials and errors were taken into account in comparing the various groups. The computation of the individual scores was based upon all the trials exclusive of the first and the last four errorless ones.

The learning was considered to have been completed when the rats made four out of five runs without error. All deviations from the true pathway were counted as errors. It seemed sufficient for the purpose to take account of two kinds of errors only, namely, entrance into cul de sacs which were designated as A type, and retracings which were designated as B type errors. A retracing was not

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* Average time for the various groups is represented by the harmonic mean, the formula for which is

$$H = \frac{1}{\frac{1}{N}\sum\left(\frac{1}{m}\right)}$$

counted as an error unless the rat turned a corner. This usually consisted in making a U turn around a partition. Frequently these turns were made around a cul de sac instead of a partition, but such turns were counted as only one error, since there was a potential error in the cul de sac. A cul de sac error was counted when the animal entered sufficiently far to include more than one-half of its body length in the alley. No attempt was made to differentiate between this minimal error and one in which the whole length of the blind alley was traversed since the criterion of time registered this difference with some degree of precision.

The Maze Learning

It is clear that the validity of the results for any method of equivalent grouping for comparative purposes must be contingent upon the degree to which the learning is properly motivated, highly purposeful, and performed with maximum effort by the various subjects. In order to achieve such a situation the purely random, excess activity should be reduced to the minimum. To accomplish this in the present study the rats were given three guided runs in the maze, the first one of which was not counted in the total score. The guidance consisted in closing up all cul de sacs.

The first free run over the true path-way enabled the rat to discover that the maze was not merely a new kind of cage into which it had been placed but that it led to food. After that discovery was made the subsequent runs were generally highly purposeful and vigorously directed. The other two guided runs, which were counted, served to fixate the general sense of direction of the way to the goal so that when the guides were withdrawn there was less confusion with its attendant piling up of errors and loss of time.

The usual procedure in preparing the subjects for their learning was to remove them to the cages near the maze. This was done four days before the tuition began. During this time they were fed in the food-box of the maze itself. They were allowed to feed and to play around on the top of the maze for three quarters of an hour the first day. After that they were allowed to feed fifteen minutes per day until the last before the tuition began. During the twenty-four hours immediately preceding their tuition they were given only ten minutes in the food-box and that was usually at the beginning of that twenty-four hour period.

It was customary to run ten or twelve rats during a tuition period. On the first day they were given three guided runs and one unguided run each. The second day they were given ten runs, and on the third and each succeeding day thereafter necessary to complete the learning they were given twelve runs.

After the first five or six trials they were able to run the maze in less than a minute with but few errors. Then they were each given two runs in succession in each of the practice periods. The practice periods were divided equally between the morning and the afternoon with three in each. Roughly speaking, each rat was given one turn of two consecutive trials in the maze in each sixty or ninety minutes.

A few bites of food were allowed as a reward at the end of each run. Then at the close of the day's practice they were allowed to feed for ten minutes. The first three groups (CI, EII and EIIb) were fed in the maze, but all later groups were fed in their cages. The total feeding time for any one day would not aggregate more than twelve or fourteen minutes. This was made to vary, however, in certain cases, according to the general apparent condition of the rat. Some would lose weight rapidly and appear to be excessively hungry. They were given more to eat, whereas those that seemed to be less affected by the comparative fast and consequently less eager to run were rigorously denied.

It was generally somewhat more difficult to secure the proper motivation of the control groups. They appeared to be somewhat less active and fatter than the smoked rats. They seemed to require less to eat during the tuition period, they were less eager to run, and their loss of weight appeared to be less.

The experimentals were obviously less curious and less timid than the controls. The ordeal of being bundled into containers, carried out of the room, and put into the smoker each day served to provide them with a varied experience that was probably in their favor. All other things being equal, the daily handling, change, etc., probably provided a stimulation and an experience that made for better learning records on the part of the experimental groups.

Hunger was the dominant motive relied upon in the experiment. However, this was powerfully augmented by other strong incentives, such as the natural curiosity which characterises the rat and leads to extensive exploratory movements and the vigorous escape movements that usually result when a rat is confined in a new or strange place. A rat that is not hungry will usually run the maze in fairly good time. It has been shown that rats will even learn a maze without the incentive of food, but when this incentive is added the learning progress is greatly accelerated (25).

It occasionally happened that a rat would not run. In several different trials they would venture only a few turns away from the entrance. Then they would return promptly and spend many minutes merely sitting or working aimlessly at the covering or the sides of the alley-way. These were necessarily eliminated. The condition was apparently due to various causes, such as an occasional case of "snuffles", or some indisposition superinduced by the preparatory and training regimen. The failures certainly did not in every case indicate inability to learn. In a few cases where it was convenient to do so, inactive and indisposed rats were put over and started again with a later group. In every such case the subject achieved a fair average record. In the whole experiment there were four normal and seven experimental rats that failed out of a total of 168 employed.

There were several, however, that plainly were too stupid to learn the maze. There was one male, for instance, that did succeed in getting around twenty-two times. But its method of procedure was so haltingly interspersed with starts and stops that it could have gained no possible idea of the consecutive nature of the maze. Its behavior on the twenty-second trial was characterized by practically as much uncertainty as that of a normal rat in its early trials. Its practice periods were, moreover, distributed over a period of five days, but even though it spent several thousand seconds in the maze it made but little progress in eliminating errors. Others simply refused to exert themselves sufficiently to find their way out.

Control by Guidance

The Gestalt viewpoint that "learning is a repeated goal-activity" was basic to this experiment. This holds that the goal must be perceived, and when it is the body moves towards it under stress, or tension, by the law of least action.

It was the function of the first run to establish such a goal and set up a tension towards it. As such it was not counted in the final summation of the rats performance. Such a procedure seemed justified in view of the fact that the conduct of the great majority in that first trial clearly indicated that their movements were purely random. The more agressive, bolder rats would press steadily forward and arrive in the food-box in a relatively short time, while the others vacillated back and forth in their movements, finally arriving after varied lapses of time.

Some failed at first to move sufficiently far to arrive. It was clearly demonstrated in a number of instances that rats will hardly sustain their exploratory or escape movements in any vigorous manner for more than five or ten minutes at a time. Those that failed to discover the food-box usually came to rest near the entrance at the end of that time, and many minutes would thus be spent in comparative inactivity. It was found to be better to remove them from the maze as soon as they ceased their aggressive efforts and to replace them in the maze for a second attempt to complete the run after an hour or so. As a general rule they attacked their problem with much vigor. In a few cases it was necessary to allow three or four new starts before the run was finally completed.

Theoretically it would appear that those rats which spent much time in the maze in completing the first trial would have a distinct advantage over those that took but a few seconds, but practically the advantage was on the side of the latter. It was manifestly a distinct advantage when one happened to discover that the way to the feed-box and freedom was by moving forward steadily. Those that arrived by a large series of oscillations were apparently confused. The tendency was to repeat the same wavering movements upon the next trial. So it appeared that what was learned during the first excessive period of time had largely to be unlearned.

The next two trials were also guided, and the records make it clear that this was not unwise. The principal thing that was learned during the initial trial was that the maze offered a way to food and freedom. Many that made the discovery by means of a large number of retracings certainly had no clear idea as to how that discovery was made. Their behavior in the second, and sometimes the third, trial clearly demonstrated this fact. Their movements were much more eager and purposeful than the first had been, but there was very frequently that same tendency to retrace the path. It is practically certain that such rats would have been hopelessly confused and lost, if they had been placed in the open maze without guidance for the second trial. Some spent as much as ten minutes and amassed as many as fifty-two errors on the second trial even though they had gone around once before. If the guides had been out, it is difficult to believe that they would have found their way around under an hour, and perhaps much more time than that would have been required. Some experimenters report time for initial trials varying from three, fifteen, or even twenty-five hours and that in relatively simple mazes. In a maze as long and difficult as the one here used, it is evident that in many instances the time required would have been enormous.

It was to eliminate this excessive adding up of time with the consequent amassing of errors that this method of control was used. Considerable argument has been offered against the validity of the maze experiment, and this has largely been because of this factor of uncontrolled time and errors with the extreme spread which usually results. Because of this it is charged that it is impossible to duplicate results (14). A more conciliatory attitude than the one which would eliminate the maze experiment entirely is one which seeks more refined methods and more rigid control. Such must of necessity be done, if the maze experiment is to represent more than a mere approximation to truth, or, at best, a fair degree of probability.

The present research probably achieved results that were more uniform than is ordinarily the case. It is clear that the results achieved by this method of control represent more nearly the maximum learning effort and ability of the subjects than the standard method could possibly accomplish. This is by virtue of the fact that the purely random, excess activity was sharply reduced. And unless conditions are so controlled that the groups to be compared perform at their highest level of ability, quantitative measurements for group comparisons must be open in many respects to serious question.

But what did guidance do to the learning? Figure 4 below, which compares the learning curve for twelve subjects trained by standard methods in a maze somewhat similar to the one used in this experiment with a group of thirty-five controls, shows that the first and principal effect was to cut down the initial random activity. This served to launch the subjects early in the series upon a very purposeful and highly directed learning activity. The desirability of doing this was clearly sensed by Pechstein more than fifteen years ago and forcibly stated by him in the following trenchant paragraph:

> It appears almost conclusive from present data that the retracing and entering into blind alleys, made possible by this retracing are practically useless items. Graphs for the rats learning Maze A show that retracing is a negligible factor long before the first half of the number of required trials has been made; that the return cul de sacs cease to play any part after the first two fifth of the trials ....; that the forward directed runs are almost identical in number and in distribution throughout the entire learning period and that they and they almost solely determine the learning curve for the last half of the tuition period. This seems to indicate that the beginning trials are very wasteful when waste is permitted; that the maze is never mastered until the rat finally settles down to the difficult task of forward elimination of errors; that the early trials do not measure learning but primarily the extravagant and useless expenditure of energy. This would argue that the retracing is mainly of no efficiency in learning and hence should be disregarded (22:18).

A reference to the figure will show that this is exactly what has been accomplished in effect by the present method. The guidance served to bring the rats in the present experiment to the same point in the learning series at stage two that the others had reached in their third stage, and that with only a mere fraction of the lost motion that these had suffered. From that point on the two curves are strikingly similar; in fact if the one were moved over only one

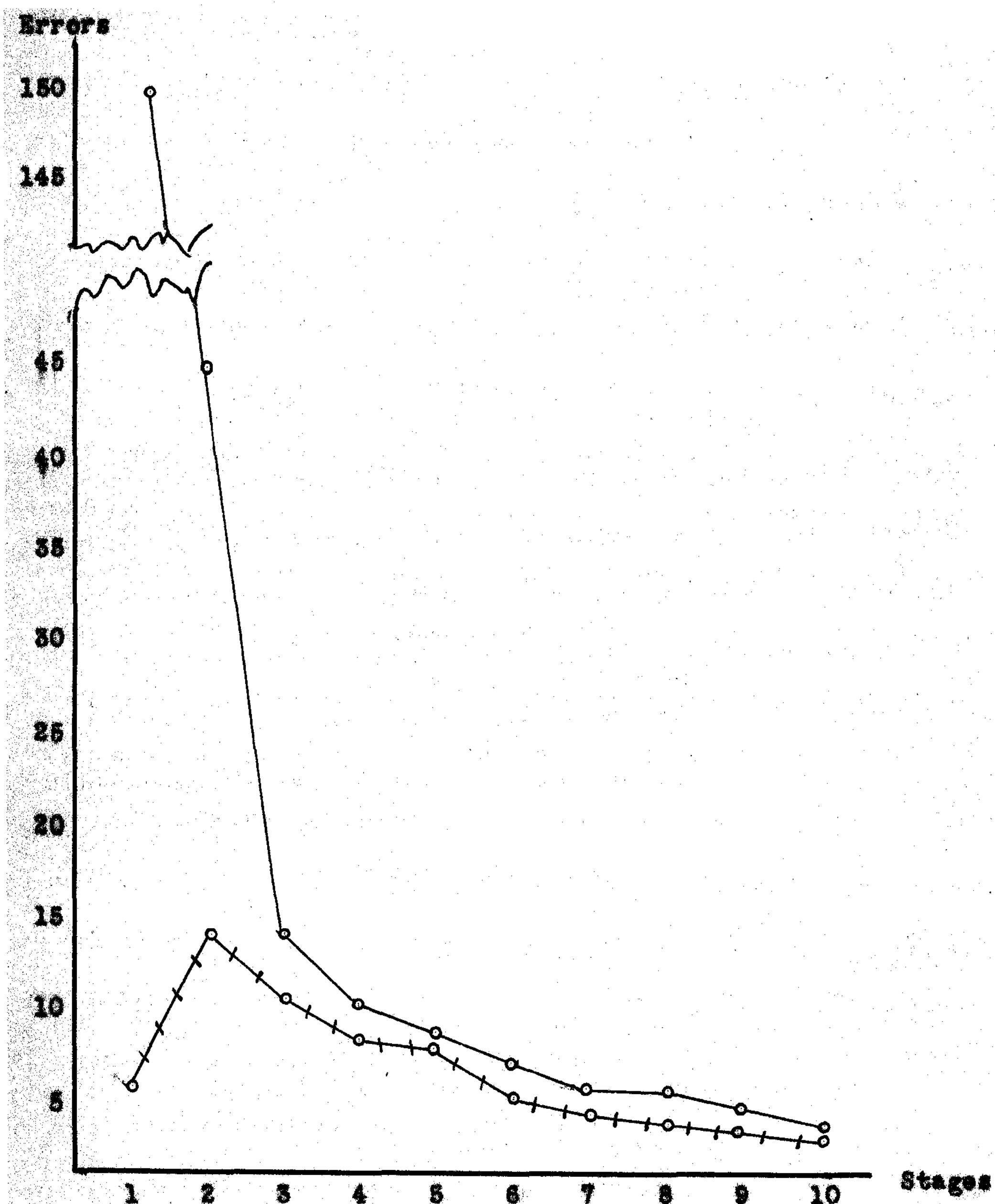

Fig. 4. A comparison of one of the original curves with a standard curve to show the effect of guiding the first three runs. The standard curve is from Pechstein representing the performance of twelve rats; the original curve is for control group I representing thirty-five rats.

——————— Standard curve
-+-+-+-+-+- Original curve

stage the two would practically coincide throughout their entire lengths. The records will show in each case that by stage two and stage three respectively the rats had "finally settled down to the difficult task of forward elimination of errors."

Figure 5 shows in detail the effects of guidance as reflected in the first eight trials. The first trial is the uncounted one. It appears from the graphs that the relative positions of the three major groups would be unchanged by its inclusion in the results. This holds true for comparatively large groups; but for finer comparisons with smaller groups the inclusion of this run would be disastrous. For instance, one control rat took about forty minutes to complete the first run. That excessive amount of time tends to be neutralized when it is averaged in with the records of several dozen others; but it would completely offset the record of the litter of which this one was a member, and practically destroy its value for comparative purposes.

The records show that there were some differences between the groups in their behavior during the first runs. (See Table I) The control groups grasped the essential idea of the maze somewhat more readily than the experimentals did. For instance, of the first generation of thirty-five controls (CI group), nineteen made perfect runs during the second trial, and twenty-nine of the thirty-five made perfect runs on the third trial. This record was not approached by any experimental group.

The experimental groups rather uniformly evidenced slightly more confusion and uncertainty during the first few runs. A probable

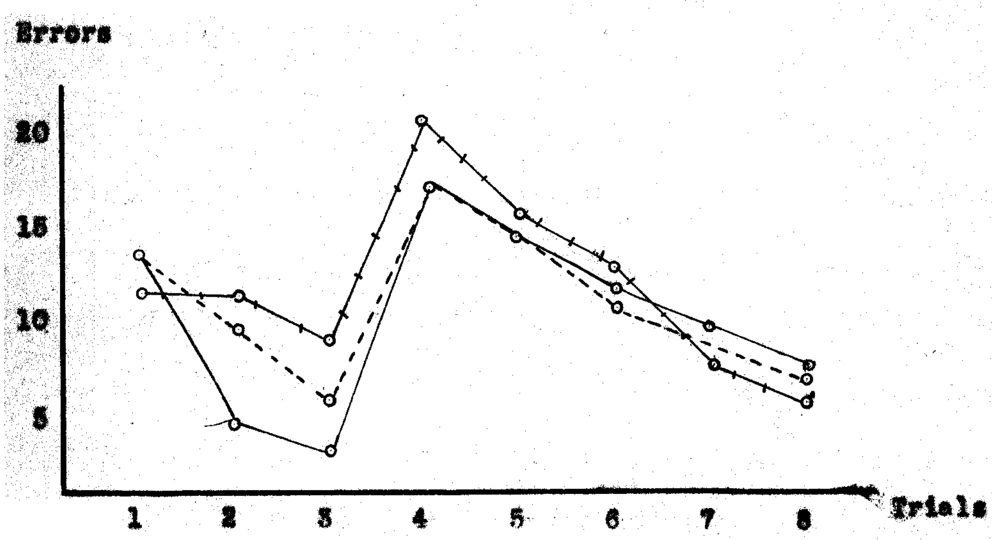

Fig. 5. Curves of errors showing the effects of guidance on the first eight trials.

———— Control groups (CI, CII)
- - - - - Five gram experimental groups (EI, EII, EIII)
—+—+—+— Ten and twenty gram experimentals (EIIb, EIIIb)

TABLE I

ERROR AVERAGES FOR THE FIRST EIGHT TRIALS OF THE VARIOUS TUITION GROUPS

Group	Trials							
	1st	2nd	3rd	4th	5th	6th	7th	8th
CI	18	6	3	18	15	10	10	8
CII	9	4	3	18	15	15	10	9
M	14	5	3	18	15	12	10	8
EI	15	13	4	20	11	14	12	7
EII	12	7	7	19	25	11	8	8
EII	14	9	5	16	9	10	8	7
M	14	10	6	18	15	11	9	7
EIIb	7	10	3	28	15	11	10	7
EIIIb	17	14	13	15	17	15	7	5
M	12	12	9	21	16	13	8	6

result was that they tended to mass their learning during the first part of the process. Their repeated traversings of sections of the maze apparently served to stamp in the knowledge of the true pathway to their later advantage. On the other hand, the controls tended to distribute their learning with the result that the necessary number of trials was increased as well as the time.

The effects of the relative amounts of massed effort in the initial trials will be studied more in detail in Chapter IV, and the effects on the entire learning curve will be noted. It would be interesting to know what the results might have been if all retracings during the guided runs had been prevented. It is a plausible guess that the experimental groups would have been handicapped somewhat. However, there tends to be a striking similarity in the curves as indicated in Figure 5, and this seems to be indicative of the fact that all groups attacked the problem in much the same way and that all profited much the same by the method of guidance employed. The efficient causes which effected any significant differences in the various groups are probably farther to seek than can be ascertained in this part of their learning activity.

Distribution of Practice Periods

The method of distributing the practice differed from the usual procedure. Whereas the standard method distributes the practice so that the rat makes but one or two runs in each twenty-four hours, the present method provided for six practice periods in each twenty-four hours. Three of these were given in the morning and three in the afternoon, and they were spaced approximately from sixty to ninety minutes apart.

There seems to be general agreement that distributed practice is more efficient than concentrated practice. Lashley's experiment led him to the conclusion that within limits as yet undetermined concentrated practice is less efficient than distributed. Unfortunately, however, the animals which he used were not accustomed to being handled, and he observes that much of the retardation was due to the avoiding reactions of those used in the concentrated practice. One of his major conclusions regarding the difference between the two types of practice is as follows: "This is due to factors which arise from the particular methods of training used, peculiar to the maze problem, and not to the influence of time relations upon the process of fixation of new functional nervous connections." (17:367) In this latter position he is undoubtedly at variance with much accepted opinion.

Wheeler's position is typical of another viewpoint which places much emphasis on the time element in its function of fixation. He emphasizes maturation as one of the major conditions of learning, and stresses the essential nature of recess periods. The following summary serves to show the relation of this factor to all the other elements in the learning process according to his theoretical formulation.

> Finally, the learning process proves to be a form of intelligent behavior that inevitably takes place when the organism faces problem situations repeated at intervals of time. It is a function of (a) maturation, (b) the repetition of stimuli, (c) the time intervals between repetitions of stimuli, (d) the relation of the problem to the learner's level of maturation, (e) the completeness with which the stimulus-pattern is repeated and (f) the degree of tension under which the learning is behaving. (24:325)

This question of the time interval between practice periods is an intriguing one. How many practice periods should there be in twenty-four hours? Is only one adequate for efficient learning, or would five or six be too many? Is two minutes of actual running time in twenty-four hours adequate, and is ten or fifteen minutes too much?

The method used in this research was a concentrated one. The guidance served to eliminate the tremendous waste of time for the first few runs, thus making all trials from first to last relatively uniform. It had the force of largely shunting the learning around the preliminary stage of maze learning which Pechstein calls the stage of elimination, with its enormous time expenditure, and introduced the subjects very early in the process to the stage of mechanization.

Concerning the significance of this latter stage for human maze learning he gives the following apt characterization:

> Tendencies to enter cul de sacs, to retrace, etc., are still present but these are swamped in the rapid forward-going activity. The function of this period is to render definite the elimination of these errors and to increase the speed of the run. Exploration has now no place. The activity is well on the road to the habitual level. Its momentum is its major guarantee of success. This is the time for massed effort. By repetitions of the successful runs, the tendencies to error become less and less liable to function, as the fixation proceeds rapidly and surely. In a strictly psychological sense, the subject who hesitates is lost. He can now drive out of the series the danger-giving elements and so render their elimination permanent. In distributing his effort, such permanent elimination is certainly less slow in attainment. Efficiency demands massing of the learning. (22:63,64)

Of course strictly massed learning* would be impossible for rats, but it was felt that a frequency much greater than one or two trials a day would make for greater efficiency. The plan of giving three guided and one unguided runs the first day; ten runs the second day, twelve runs the third day, and twelve runs on each succeeding day necessary for the completion of the learning process was therefore adopted.

The manner of distributing the runs was as follows: In the morning of the first day, each subject was given two runs, separated by an hour or more, in the maze with all the cul de sacs blocked. The rats were taken in turn, and each came in that order for subsequent turns. In the afternoon each was given a guided run and one unguided run. On the following day and for each succeeding day three practice periods in the morning and three in the afternoon were given each

* "Massed learning" as here used implies continuous application to the problem until it is learned.

subject. On the second day in the first period in the forenoon and in the first in the afternoon single runs were given, but in the other periods two runs in succession were given. The records seem to indicate that it might have been better to have had more practice periods separated by shorter intervals but with only one run in the period instead of the two for there was a rather uniform tendency for the second run of a practice period to be slightly higher in time and errors than the first. *

That this amount of practice was not excessive must be apparent when it is considered that before the end of the second morning the rats were able to run the maze in less than a minute. That means that after the first day they were spending less than ten minutes a day in the maze. It seems entirely certain that the rats represented in Pechstein's standard curve above were running the maze in about a minute by stage three or four. They were getting two runs a day, so for the last eight days of their learning they were probably spending less than two minutes a day in the maze.

The superiority of a more concentrated program of learning may be reflected in the fact that the group representing this research completed their learning with an average of twenty-one trials whereas

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* A serious effort was made to train all groups under conditions that would secure their maximum performance. This necessitated an occasional variation in the method of procedure. Groups EIII and EIIIb seemed to be so small and puny that their preparatory regimen was reduced to two days instead of four. If a rat became frightened or diverted from its goal-seeking by any unusual disturbance, it was taken out of the maze and the record for that partial trial was ignored. It occasionally happened that a rat or a group showed clearly that they were not hungry enough to make a determined effort to get through. In such cases the learning was promptly postponed for several hours in order to secure the satisfactory motivation.

the other group took twenty-seven trials with the two mazes being practically equivalent. There may have been some saving in time also throughout the stage of mechanization.

Summary

The animal subjects in the experiment were white rats which were very closely related. This fact together with the rigid control of variable environmental factors served to secure groups that represented a very high degree of equivalence. The method of training employed, involving guidance and concentrated practice, resulted in a material saving of time and effort on the part of all tuition groups.

CHAPTER III

SOME PHYSICAL EFFECTS OF TOBACCO SMOKE

There is no evidence from this experiment to indicate that tobacco smoke affects rats and men alike. In so far as scientific opinion has ventured a statement, it at least voices a preponderant doubt concerning supposed parallel effects. Such doubts are valid as touching the superficial effects, at least. However, if there is an insidious poison in tobacco smoke that deteriorates nervous tissue and causes functional and organic lesions, then it would appear that some of these effects would be produced in the rat subjects. It is the purpose of this chapter to indicate a few of the more obvious effects of tobacco smoke on the purely physical functions that were observed.

The typical reactions of the rats to the tobacco smoke were interesting. In only a few instances did it appear to make them sick. In those cases the rats manifested bodily symptoms of mild poisoning such as writhing and squealing. But this condition seemed to exist for no more than ten or fifteen minutes after they were removed from the smoker. After that their behavior in the cages seemed to be perfectly normal. In no case could it be detected that they had in any degree formed a tobacco habit.

The smoke treatment was obviously very severe. At the first trace of the smoke in the box the rats invariably made frantic efforts to escape. Then as the fumes became heavier and thicker, they became quiescent, lying with their eyes closed, their mouths open and their noses thrust as far as possible into the corners of the cages. The breathing was labored, and there was every sign of great bodily discomfort. Salivation was greatly increased. Large drops of saliva dripped from their half-open mouths, thoroughly wetting their entire front quarters, and ran on the floor of the smoker.

It might be expected that in due time the rats would become habituated to the smoking conditions so that the peculiar bodily symptoms of disturbance would disappear. But such was not the case. In fact, some females that were smoked almost daily for several months seemed to evince those peculiar reactions in increasing measure. A single puff of smoke blown into their faces sufficed to start the abnormal flow of saliva and to call out the apparent fear reactions.

Effect on Reproduction and Viability

There has been only a very limited study made of this phase of the tobacco problem. Chapter I lists the major studies that have been made. Such evidence as there is appears to be contradictory. The studies by Depierris and Wright, referred to in Chapter I, indicate that tobacco smoke lessens the generative capacity, whereas Nice's study shows clearly an increased fertility resulting from exposure to tobacco fumes.

Strangely enough, the present experiment confirms both positions. This research shows that tobacco smoke acts as a stimulant to the reproductive processes up to a certain point; after that point has been passed its effects are destructive.

The accompanying tables II to VIII give the group records on this point. The row labelled "number died" refers to those that were still-born or that died from natural causes within a few days.

Two of the experimental groups, EII and EIII, showed unmistakeably the stimulating effects of the tobacco fumes. The EIII group is a much more remarkable and clear-cut case, however, than the former. These were first litter rats, whereas the EII group represented second litter rats; and there is normally a material increase in litter size with the second litters. Donaldson's tables show that conclusively (7:25).

The EIII group represented the first litters of the EII group, and they averaged eleven to the litter with the range from eight to fourteen. These were somewhat stunted, but, except for one whole litter of ten that died within a day or two, they seemed to be rather vigorous. This group with their own progenitors, the EII group, averaged 10.5 per litter, or 116 young in eleven litters. The effects on fertility are shown by comparing these groups with the controls. In seventeen normal litters born there were 145 young, or an average of 8.5 young per litter. The litters of the experimentals thus averaged 19 per cent larger than those of the controls.

This part of the experiment agreed with the observations of Nice. His smoked mice were much more prolific than the controls. However, their viability was much less. Herein the present experiment differs somewhat from his. Of the 145 young born in the control groups, thirteen were either still-born or survived but a short time;

TABLE II

NUMBER OF YOUNG BORN AND VIABILITY OF THE CI GROUP

	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Total	Mean
Number born	7	10	9	10	3	4	43	7.2
Number died	2					3	5	

TABLE III

NUMBER OF YOUNG BORN AND VIABILITY OF THE CII GROUP

	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Total	Mean
Number born	9	10	9	8	8	8	52	8.7
Number died	1			1		2	4	

TABLE IV

NUMBER OF YOUNG BORN AND VIABILITY OF THE CIIb GROUP

	Set 1	Set 2	Set 3	Set 4	Set 5	Total	Mean
Number born	8	11	9	10	12	50	10
Number died		1		1	2	4	

TABLE V

NUMBER OF YOUNG BORN AND VIABILITY OF THE EII GROUP

	Set 1	Set 2	Set 3	Set 4	Set 5	Total	Mean
Number born	7	11	11	10	11	50	10
Number died						0	

TABLE VI

NUMBER OF YOUNG BORN AND VIABILITY OF THE EIII GROUP

	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Total	Mean
Number born	8	12	10	14	12	10	66	11
Number died				2		10	12	

TABLE VII

NUMBER OF YOUNG BORN AND VIABILITY OF THE EIIIb GROUP

	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Total	Mean
Number born	2	3	7	5	10	6	33	5.5
Number died			2		10	1	13	

TABLE VIII

NUMBER OF YOUNG BORN AND VIABILITY OF THE EIV GROUP

	Set 1	Set 2	Set 3	Set 4	Set 5	Total	Mean
Number born	5	1	7	3	1	17	3.4
Number died	3	1	6	3	1	14	

whereas twelve out of 116 in the two experimental groups mentioned were not viable. Of the twelve which died, ten belonged to one litter. On the whole there was much less mortality among the experimentals of these groups than of the normals.

But the records for the EIIIb and the EIV groups tell a different story. (See Tables VII and VIII.) Here the experimental factor of tobacco smoke proved to be disastrous. The EIIIb group was composed of the siblings of the EIII group, and they represented the second litters of the EII group breeders. The EIII group represented the highest degree of prolificacy of all the groups; on the basis of normal relative size for first and second litters, the EIIIb group should have been larger. As a matter of fact there were only thirty-three young born in six litters, averaging 5.5 per litter. Of these thirteen were not viable. The average litter size of this group is, therefore, seen to be 50 per cent less than that of their own siblings, and 35 per cent less than the normal litters.

The EIV group, which were the offspring of the selected breeders from the EIII group and represented the fourth generation of experimentals, showed the most marked effects of the smoking process. Only seventeen young were born in five litters, and of these only three survived.

Effect on Weight and Growth

The effect of tobacco smoke upon growth of young animals has been studied by several experimenters. The fact is probably definitely established that tobacco smoke does have a retarding effect upon rate of growth. The present experiment is in agreement with this finding, but it adds further data in showing some hereditary effects as well.

This effect upon weight and growth may best be seen in a comparison of several groups representing three generations of experimental rats and a control group. See figure 6 below. All were spring and summer rats. The control group and the first and third generation rats were nearly the same age; they were raised under identical conditions, growing in adjoining cages.

The control group (CII) and the first generation of fumed rats (EI) were litter-mates from six litters. These litters, totaling forty-nine young, were divided into two equal groups, one of which was smoked and the other used as a control. The division was made when the young were ten days old and at that time the smoking process was begun. It was impossible in every case to determine the sex at that early age, so it happened that the division was not quite accurate so far as sex was concerned. In the control group there were ten males and fourteen females; in the experimental group there were twelve males and thirteen females. This gave a slight natural advantage to the

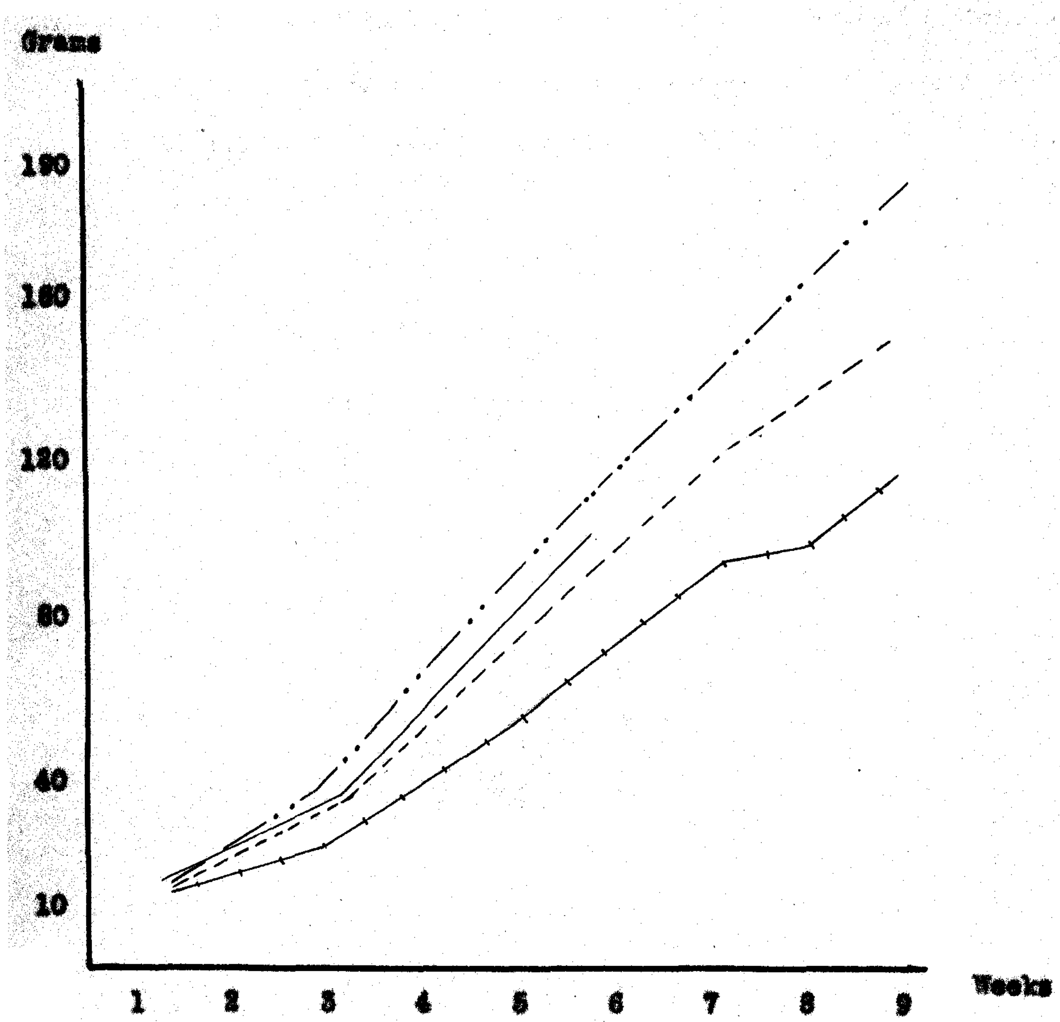


Fig. 6. Comparison of the growth curves of the first, second and third generations of the experimental line with a control group showing the effects of smoking.

experimental group, for the larger proportion of males in this group would tend to raise their average weight by so much.

The curves indicate that there was a slight but steady retardation of growth on the part of the experimentals. Tables IX and X give the weekly average weights of the two groups. At the time of the division, the two groups weighed almost the same. After two weeks of smoking the experimental group averaged 7.35 per cent lighter in weight than the controls, and after four weeks of smoking they were 8.13 per cent lighter.

In like manner comparing this control group and the second generation of experimentals, the controls were 11 per cent heavier at five weeks of age and 15 per cent heavier at nine weeks. Perhaps this difference is given greater significance by the fact that this second generation of experimentals was made up of the second litters of the original stock. Donaldson's tables, as well as practical observation, indicate that the second litter rats are on the average the largest and hardiest of all. On that basis this group should have been superior to the controls. It would seem, then, that the smoke might have been responsible for the loss of a larger percentage of growth and weight than appears from the comparison.

The third generation was the offspring of the second. Whereas their forbears were only slightly inferior to the controls, these were decidedly smaller. At five weeks the control group averaged 31 per cent heavier; at nine weeks they had increased their gain to 37 per cent. The significance of this difference is increased by the fact that there was an average difference in the ages of the two groups of

TABLE IX

AVERAGE WEEKLY GROWTH OF THE YOUNG OF THE EI AND CII GROUPS

Set	1st week	Division of sets	3rd week	5th week	9th week
1	14	CII	41	96	180
		EI	41	90	
2	13	CII	39	90	
		EI	36	78	
3	13	CII	45	94	180
		EI	43	86	
4	15	CII	50	100	184
		EI	42	94	
5	13	CII	39	86	
		EI	36	85	
6	11	CII	38	77	
		EI	33	75	

TABLE X

COMPARISON OF THE AVERAGE WEEKLY GROWTH OF THE EI AND CII GROUPS AFTER THE SMOKING PROCESS BEGAN

Group	Average weight at time of division	2nd week	3rd week	4th week	5th week
CII	20.3	54.4	81.9	115.6	117
EI	20.4	50.4	78.5	106.2	108

Weights are in grams.

only three or four weeks. They grew in adjoining cages, and all conditions were equal for the two groups save the one factor of tobacco smoke.

Comparing this third generation of experimentals with their own progenitors and the litter-mates of these, the second generation experimentals, the deleterious effects of tobacco smoke on weight and growth are further seen. It is a significant fact that the litter-size of this generation averaged unusually large, but some died and others were divided around so that no female suckled more than the usual number, that is, about ten. The curves show that at three weeks of age this group averaged 13.5 per cent less in weight than their forbears; at five weeks they averaged 27.5 per cent less and at nine weeks they were 25 per cent lighter.

The records clearly show that tobacco smoke has a stunting effect upon growth, and the evidence from the later groups indicates that this stunted condition is transmitted to offspring. The selected breeders from the third generation - eight females and three males - were decidedly abnormal with respect to the matter of fertility as explained in the previous section. Only three surviving young from these contributed any evidence for effects upon the fourth generation. These were not subjected to the smoking process, and, presumably, they held a natural advantage in that only two in one case and but one in the other were suckled by a female. The two were discarded at forty days of age, at which time they averaged ninety grams in weight which was about 21.7 per cent lighter than the controls. The other was discarded at thirty-three days when it weighed sixty-seven grams, or about 23 per cent lighter than the controls.

Further information on the effects of tobacco smoke upon growth is derived from a study of the selected breeders from the different groups that were kept for several months. Figure 7 shows the effects of prolonged smoking on the ultimate body weight of adult rats.

The first generation control group (CI) was not included in the previous discussion based upon figure 7. These were born in late winter and were somewhat inferior in size to those that were born in the spring or summer. Table XI gives the complete record of their growth. The EII group were their own siblings. The fact that they were winter rats and the EII group were second litter rats as well as spring rats probably would make for a considerable difference in the general size and rate of growth of the two groups. It is only reasonable to suppose, therefore, that the smoking process did cut the weight of the EII group so that the two curves representing the growth of the two groups are very close together. Table XII gives the record of the growth of the EII group.

TABLE XI

WEEKLY GROWTH OF THE YOUNG OF THE CI GROUP

Set	1st wk.	2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	9th wk.	10th wk.	16th wk.	31st wk.
1		25	35	55	78	90	98	158	195	210	293	
2	11	22	35	53	75	102	111	120	145	170	214)	
3	12	22	36	53	82	109	115	129	158	175	225)	258
4	12	22	33	52	71	101	119	138	157	173	203)	
5	13	25	38	55	86	110	135	148				
Av.	12	22	35	53	77	102	115	134	157	176	225	258

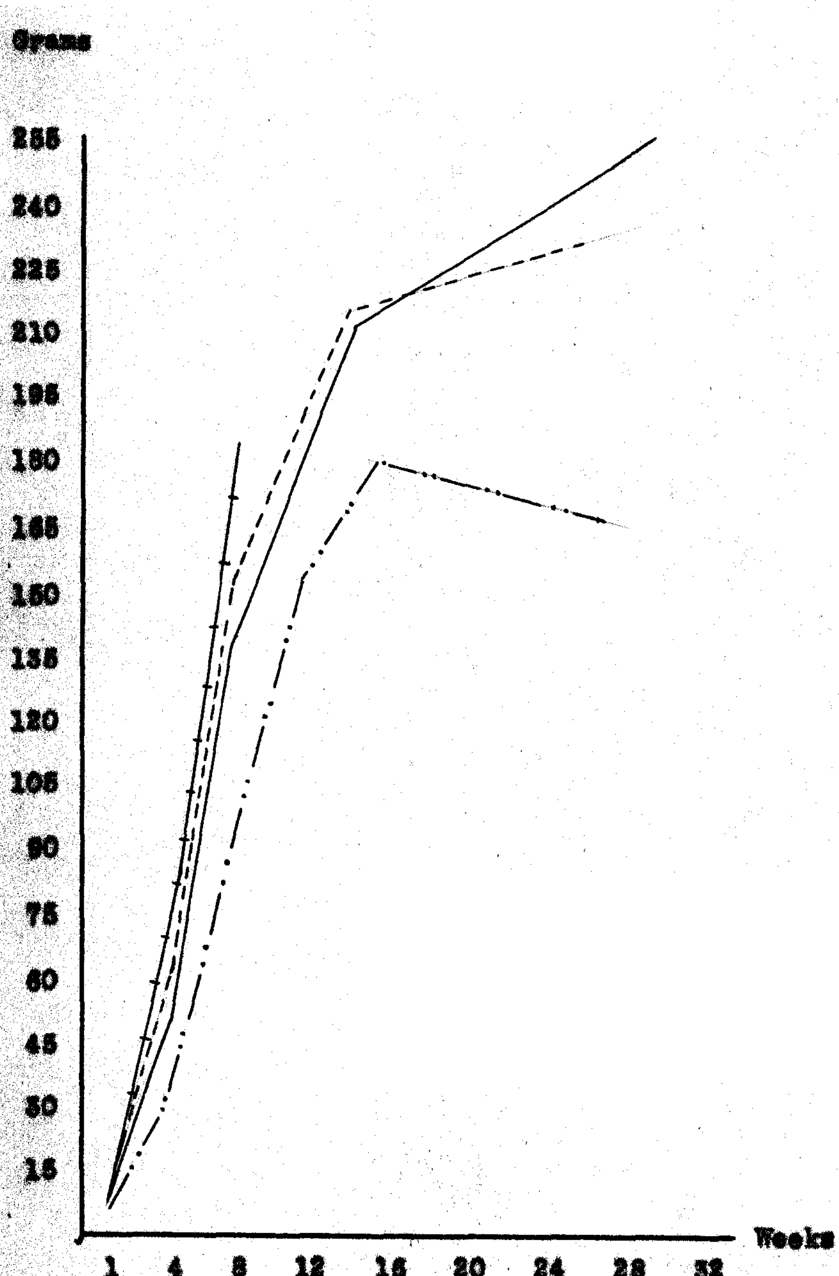


Fig. 7. Growth curves showing effect of prolonged smoking upon adult size. Males were not included after the 16th week. Possible hereditary effects of smoking may be seen in the size of the offspring relative to the parent stock (CII to the CI group, and EIII to the EII group).

———— 1st generation control (CI)
—+—+—+— 2nd generation control (CII)
- - - - - 2nd experimental (EII)
——..—— 3rd experimental (EIII)

TABLE XII

WEEKLY GROWTH OF THE YOUNG OF THE EII GROUP

Set	1st wk.	2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	9th wk.	10th wk.	16th wk.	25th wk.
1	12	26	46	64	86	113	113	165	195	210		}
2	12	20	32	50	81	110	125	135	157	180	252	} 235
3	11	21	35	55	85	100	120	135		165	217	}
4	12	23	38	57	70	106	127	153	147	157	237	}
Av.	12	22	37	56	80	107	122	149	156	174	229	235

The upper end of the curves shows a significant trend that is confirmed by the growth record of the EIII group. This indicates that the normal rats tended to make a longer and larger growth development than those that were smoked. After the sixteenth week the males were not included in the weight averages for they were discarded, so the final records were made by the females. Of these there were five each in the CI and the EII groups and seven in the EIII group.

The EIII group, whose complete growth records may be studied in Table XIII, shows clearly the stunting effects of smoking. At sixteen weeks of age, eight females and three males averaged 21 per cent lighter in weight than their own progenitors, the EII group, did at that age. It should be stated that this represented a slight gain on the part of the EIII group, for it was seen that at nine weeks of age they were 25 per cent lighter than their forbears. This gain was, apparently, largely made by the males of the group, for at twenty-two weeks the seven females averaged about 26 per cent less than the five EII females.

TABLE XIII

WEEKLY GROWTH OF THE YOUNG OF THE EIII GROUP

Set	1st wk.	3rd wk.	5th wk.	6th wk.	7th wk.	8th wk.	11th wk.	16th wk.	22nd wk.
1	11	29	51	69	86	105	150)	)	
2	11	32	63	88	105		165)	180)	171
3	11	25	55	75	86)	94)	135)	)	
4	8	29	66	90	98)	)	)	)	
Av.	10	28	58	76	91	99	151	180	171

Suggestive data on the hereditary effects of the smoking process may be seen in comparing the two groups of siblings, - the CI and EII groups - with their own offspring. The progeny of the CI group, which was the CII group, are shown to be definitely superior in weight to their forbears; the EIII group is decidedly inferior to their progenitors, the EII group. These radical differences are not assignable to any known factor other than that of tobacco smoke.

No definite physical effects that were observable resulted from increased amounts of smoking. The EIIb group was a single litter which was fumed with smoke from ten grams of tobacco from their sixth to the ninth week. No tangible effects resulted from this, so the group record was included with that of the EII group as set number four.

The EIIIb group was made up of the second litters of the EII group breeders and were the siblings of the EIII group. The smoking process was not commenced with them until they were two and three weeks old. This together with the fact that they were second-litter rats may have been responsible for the fact that they averaged slightly higher in weekly weights than did the EIII group. (See Table XIV.)

TABLE XIV

WEEKLY GROWTH OF THE YOUNG OF THE EIIIb GROUP

Set	3rd week	5th week	7th week	8th week	13th week
1	40	75	117	155	205
2	25	56	86	94	154
3	33	70	107	113	
Av.	30	67	102	111	176

Summary

1. Rats that were fumed with smoke from five grams of tobacco for a period of seventy-five to ninety days were found to be 19 per cent more prolific than the normal rats.

2. Prolonged smoking of those same rats resulted in reducing the average size of their second litters 50 per cent. This average was 35 per cent less than that of the normal rats.

3. The viability of the third generation was greatly reduced, especially among the second-litter rats.

4. The fertility of the third generation breeders was 60 per cent less than that of the controls, and 67.6 per cent less than that of previous experimental rats. Moreover, there were three out of eight females that failed to reproduce.

5. The viability of the fourth generation was greatly reduced, only 17.6 per cent of them surviving.

6. Tobacco smoke retarded the growth of the rats. The first generation experimentals averaged 8.13 per cent lighter than their controls after four weeks of smoking.

7. The second generation experimentals averaged 11 per cent lighter than their controls at five weeks of age and 15 per cent lighter at nine weeks.

8. The third generation experimentals averaged 31 per cent lighter than the controls at five weeks of age and 37 per cent lighter at nine weeks.

9. The stunting effects of tobacco smoke were transmitted to progeny. The three surviving young of the fourth generation were never smoked, but at forty days of age two of them averaged 21.7 per cent less in weight than the controls. Another was 23 per cent lighter than the controls at thirty-three days of age.

10. Normal rats tended to make a more prolonged and larger growth development than those that were smoked.

CHAPTER IV

EFFECTS OF TOBACCO SMOKE UPON RATE OF LEARNING

Introduction

The nature of the effects of the active agents in tobacco smoke upon the mental processes has not been determined. The experimental literature upon the subject is largely inconclusive, and the great mass of published personal opinion and testimony regarding the effects is as contradictory as it is unscientific. If tobacco smoke serves as a sedative, with a strong tendency to depress, it might be expected to retard learning; if it acts as a stimulant, or excitant, it might be expected to accelerate learning by increasing the variety and intensity of activities available for selection and repetition.

Opinion ranges between these two opposing possibilities. The solution of the problem must certainly be sought in rigidly controlled experimentation which is adequately designed to eliminate all extraneous factors, thus insuring results that unmistakably register these effects. Such has been the purpose of this experiment. The desire for positive knowledge regarding the effects of smoking is voiced in a multitude of ways, and the interest which attaches to the general subject is far from being purely academic.

The method of study, involving the use of rats instead of humans, receives its sanction from well-nigh universal scientific practice. There is no contention that the results obtained from these animal subjects will hold for humans, yet the practice of animal experimentation has probably demonstrated the fact that such results may be regarded as at least indicative and suggestive for a parallel study of human beings.

The animals used in this experiment were all litter-mates, siblings, and the direct offspring of these. The original progenitors were very closely related, their lines having been inbred for generations. So for uniformity of all hereditary factors, nothing approaching this in human family relationships could possibly be found. Great dependence has been placed upon the equivalence of the various groups for validating the results of the experiment. Whatever may have been the defects in the method of control employed, the various groups undergoing comparison were, at least, as nearly equivalent as could possibly be obtained.

The comparative adequacy of this study may be reflected in the fact that the number of subjects used to test each phase of the problem was, generally, much larger than those used in any similar study that has come to the attention of the writer. The advantage of the larger numbers in the various groups is seen in the fact that the preponderant weight which exceptional cases bear in small groups has been largely neutralized, and the differences recorded may, to a very high degree, be regarded as resulting from the experimental variations alone.

The Problem Restated

The objectives of this experiment, together with the experimental set-up and the general method employed, have been set forth in

Chapters I and II. It will suffice, therefore, to state here that the principal aim was to discover (1) what effects, if any, smoking has upon the learning behavior of rats; (2) what differential effects may result from varied amounts of smoking; and (3) what sex-differences may be produced by it.

That final answers to these problems have not been discovered may certainly go without saying. The many months of painstaking care in the carrying out of the research have, however, yielded some data upon the tobacco problem that are new. How significant they may be is beside the point here. A mere fragment of truth may increase by so much the body of information that will ultimately give answers to many vexing questions involved in that problem.

Synopsis of the Experiment

It was not convenient to maintain strict uniformity in the technical procedure throughout the experiment. Such variations as were necessary, together with the possible effects, will be noted in the discussion which follows. Table XV gives a synopsis of the experiment, showing the different groups, the amount and duration of the fuming, the seasonal variations, and the ages of the groups at the time of training. It will be observed that three groups (CI, EII, and EIIb) were reared in the laboratory; all later groups were reared in a room in a vacant apartment. It will also be noted that the EIII and EIIIb groups were subjected to a shorter preparatory regimen than the others. Such effects as were clearly the result of the environmental interpolations as well as those resulting from varied amounts of fuming with tobacco smoke will be considered in the following pages.

TABLE XV

SYNOPSIS OF THE EXPERIMENT SHOWING
DIFFERENT PHASES AND GROUPS

Group	Daily Fuming	Amount of Tobacco Burned	No. Days Fuming before Tuition	Number of Rats Trained	Number of Rats Failed	Age in Days at Beginning of Tuition
Tuition Periods, April - July						
CI				35	1	47 - 67
EII	30 min.	5 gms.	30	28		43 - 50
EIIb	1 hour	10 gms.	62	9		64
Tuition Periods, September - October						
CII				21	3	47 - 60
EI	30 min.	5 gms.	37 - 50	23	2	47 - 60
Tuition Periods, October - December						
EIII	30 min.	5 gms.	45	31	3	49
EIIIb	3 hrs.	20 gms.	41 - 87	10	2	62 - 71

Group Differences Resulting from the Smoking

A summary of the learning records of the three major groups in the experiment, showing the effect of tobacco smoke upon the rate of learning, is given in Table XVI below. This shows that three groups of rats (EI, EII, and EIII) which were fumed with smoke from five grams of tobacco were superior to the two groups of controls (CI and CII) in all three criteria of learning. They learned with an average of 12.9 per cent less trials than their controls, their learning time averaged

17.5 per cent less, and their errors averaged 4.4 per cent less. On the other hand, those that were fumed with smoke from ten and twenty grams (EIIb and EIIIb) are shown to be inferior to the controls in two of the criteria. While they learned with an average of 6 per cent less than the controls, their average time was 24.6 per cent higher and they averaged 12.1 per cent more errors.

TABLE XVI

SUMMARY OF THE LEARNING RECORDS OF THE CONTROL, FIVE GRAM, AND THE TEN AND TWENTY GRAM RATS *

Groups	Mean Trials	S.D. Mean	Mean Time	Mean Errors	S.D. Mean
(56) CI and CII	20.1	± .897	687	116	± 5.66
(82) EI, EII, and EIII (Five Grams)	17.5	± .827	567	111	± 4.99
(19) EIIb and EIIIb (Ten and Twenty Grams)	18.9	± 1.19	912	132	± 9.06

It is thus seen that the trend of the effects of tobacco smoke upon the learning of rats was in conformity with the trend of effects upon fertility as observed in Chapter III. The results showed that the rats that were smoked for a period of thirty minutes a day with fumes from five grams of tobacco were accelerated in their learning; those

* Table reads as follows: Fifty-six first and second generation controls learned with an average of 20.1 trials, the standard error of the mean being .897; the harmonic mean of their learning time was 687 seconds; their mean errors were 116 with a standard error of 5.66.

that were fumed for longer periods were retarded materially.

The reliability of the differences between the obtained means, as computed by means of the so-called short formula, does not in some of the cases indicate any significant difference. However, the method of selection in the experiment was such that the groups would not in any sense represent a random sample. To find the standard error of the difference between related or equated groups, it is necessary to use the long formula and that cannot be used where it is impossible to correlate the groups.

> The shorter formula has been used where there is no warrant for it, with the result that the reliability of the difference as reported, is incorrect. . . . It makes the standard error appear too large and therefore makes the differences appear less reliable than they actually are . . . . Whenever a difference must be found between two related groups where the value of the correlation is truly inaccessible, the writer should call attention to the fact that the standard error as found by the shorter formula is not a real value of the standard error but merely an upper limit. (27:53,60)

Considering then that the usual statistical procedure for determining the reliability of the difference cannot give a true value in this case, the following indices must be regarded as only approximations.

Comparing the different groups in trials and errors as given in Table XVI, the following relationships are seen. The obtained difference in the mean trials of the control groups (CI and CII) and the five gram experimentals (EI, EII, and EIII) is 2.6; the standard error of the difference is 1.09. Since the obtained difference is more than twice the standard error of the difference, the chances are more than twenty to one that the difference is real. As might be expected, there is no reliable difference in mean errors. Comparing the ten and twenty gram (SIIb and SIIIb) group with the other two groups, no reliable differences in mean trials appear. An insignificant difference appears in comparing their mean errors with those of the controls. Comparing them with the five gram rats, however, the obtained difference in errors (21) is twice the standard deviation of the difference (10.3), which probably indicates that the difference is a real one.

It is to be observed that the greatest variations occur in the time factor. But no accepted method of determining the standard error of the harmonic mean exists, and therefore it is impossible to determine an index of reliability.

Turning now to a detailed study of the different group records, comparisons will be made touching all three criteria of the maze learning in an endeavor to estimate more in detail the effects of the inhalation of tobacco smoke and other factors upon learning as these were reflected in the group variations. Table XVII gives the learning records of the various groups.

It may be that the experiment registered the influence of other factors in addition to the one experimental factor of tobacco smoke. If there is a variation in learning ability attributable to seasonal changes, then this was reflected here, for the learning periods were distributed from April 18 to December 23. If environmental variations, involving changes in location and housing and offering a more stimulating life situation, influence learning ability, then this factor played a part. If there was an increase of skill on the part of the experimenter in handling the rats, this might be reflected in generally

TABLE XVII

SUMMARY OF THE LEARNING RECORDS OF THE VARIOUS GROUPS SHOWING AVERAGE PERFORMANCE IN TRIALS, TIME AND ERRORS

Groups	Trials	Seconds	Errors
(35) CI	21	709	117
(28) EII	18.6	767	130
(9) EIIb	16.9	803	134
(21) CII	18.6	651	115
(25) EI	16.6	590	118
(31) EIII	17.2	450	89
(10) EIIIb	20.7	1055	151

better records on the part of the later groups. The evidence concerning the effects of these factors, as well as that of the experimental factor, is to be noted. The synopsis of the various phases of the experiment afforded in Table XV above will serve to make some of the variable conditions and factors clear.

The experiment might well be divided into two major divisions based on the factor of environmental change and consequent variation in the matter of housing and care. It has been indicated in Chapter II, page 12, that the stock was transferred to a room in a vacant apartment during the summer season and here all subsequent groups were reared. It was clear that the new location offered a much more stimulating environment than was afforded by the seclusion of the laboratory.

The experimental groups designated as EII and EIIb with their controls the CI group were laboratory rats and represent the first phase of the experiment. Their greater degree of timidity together with their more pronounced avoiding reactions, especially in the first part of the learning series, undoubtedly accounted for a considerable part of their increased learning time in comparison with the later groups. Then, too, the experimental groups were trained in the maze during one of the hottest periods of the summer. The intense heat, an occasional buzzing fly, and the whipping of the wind through the laboratory were undoubtedly disturbing factors that influenced adversely the records of the EII and EIIb groups.

On the whole, the results achieved in the second part of the experiment are probably to be regarded as representing more nearly the maximum learning effort of the different groups under seasonal conditions that were much more nearly uniform. While the records of the foregoing groups are by no means to be ignored, yet it is the feeling of the writer that the records of the EI, EIII and EIIIb groups in comparison with their controls the CII group give a more accurate picture of the group variations that were produced by experimental factor of tobacco smoke alone.

The second phase of the experiment also marked a slight change in the method of procedure. In the case of the groups representing the first phase, the rats were smoked at the close of the day's practice. But the experimenter was concerned with such effects of smoking as were in a measure permanent and not with any temporary effects. So it was decided to discontinue the smoking shortly before the learning process began. This was done four days before in the case of the EI group, and two days before for both the EIII and the EIIIb groups. It was, of course, impossible to tell how much the mere deprivation effects may have influenced their behavior. It is clear, however, that the rats were not under the immediate influence of the active ingredients of the tobacco smoke. No data are available to show how permanent the apparent stimulating effects of tobacco smoke may be, but it is apparent that the rats were affected at least for a number of days after the cessation of the smoking process.

There was also a variation in the method of preparation in the case of the EIII and the EIIIb groups. All other groups were given a four day preparation for their learning, involving sharp reductions in their usual amound of food and offering daily opportunity for orientation with respect to the maze, but these groups seemed so puny and thin that their preparatory regimen was reduced to two days instead.

The group variations resulting from the experimental procedure may be more graphically portrayed in the frequency polygons representing the various group performances. (See figures 8, 9, and 10.) These show not only the relative position of the means of the groups in trials, time and errors but also their spread.

Some Analyses and Explanations of the Group Differences

It was, of course, impossible to account for the group differences obtained in any full or satisfactory manner. However, there seemed to be some very definite reasons why the five gram experimental rats surpassed the controls in two of the accepted criteria of learning. These may be readily pointed out. The larger meaning of these

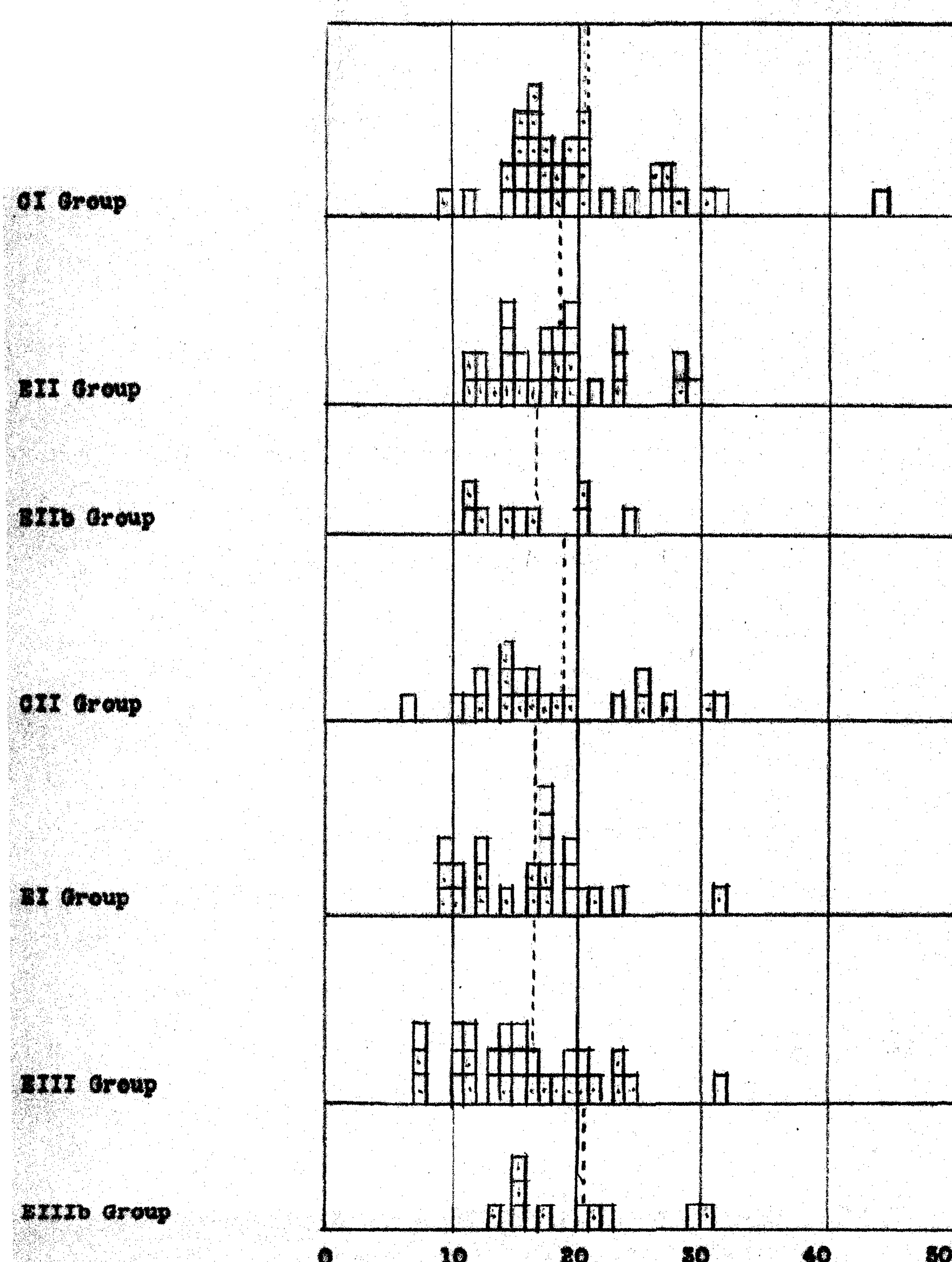


Fig. 8. Frequency polygons for comparing the number of trials required by the various groups to complete the learning. Each block represents a rat; those with dots indicate females. The ordinates indicate the frequencies; the abscissas show the number of trials. The dotted lines show the averages of the groups.

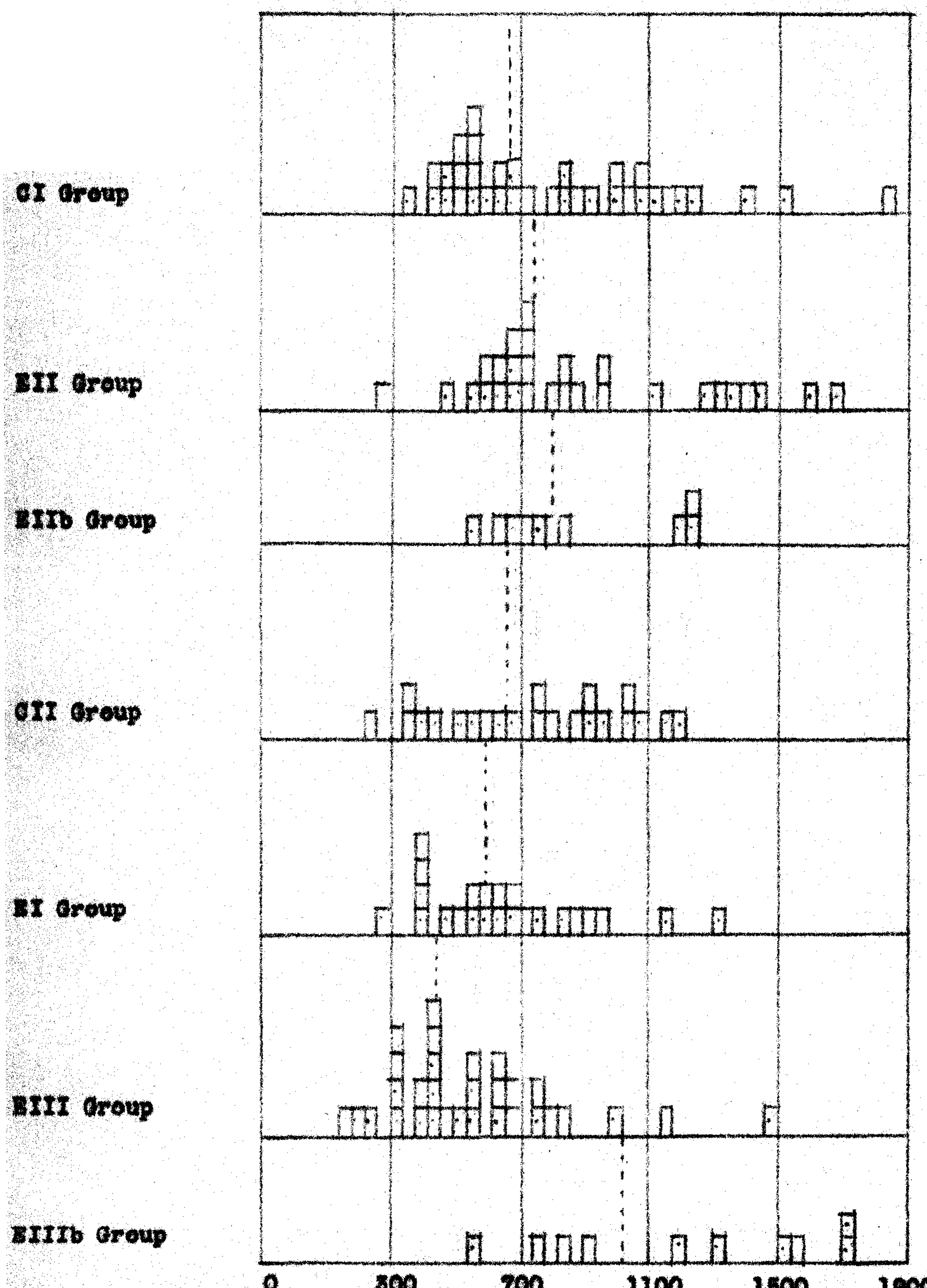


Fig. 9. Frequency polygons for comparing the time required by the various groups to complete the learning. Arranged as in figure 8. The average time is represented by the harmonic mean.

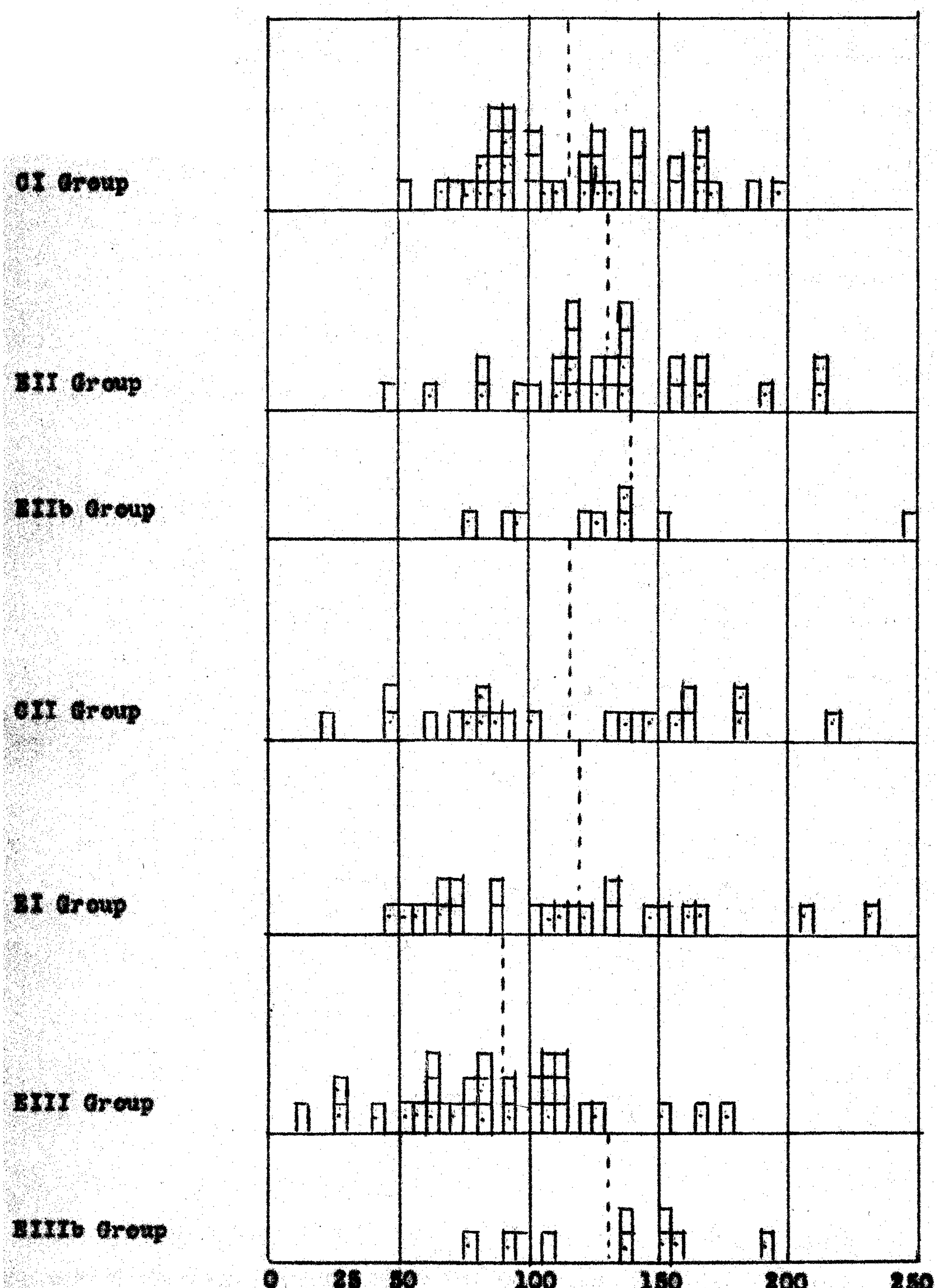


Fig. 10. Frequency polygons comparing the number of errors made by the various groups. Arranged as in figure 8.

facts for general learning situations, and for an adequate comparison of the different groups, is by no means so apparent.

1. Variability in consistent forward movement.- A significant difference resulting from the smoking process has already been pointed out, and the analysis in Chapter II together with the figure on page 29 serves to make it clear. That analysis shows that the smoked rats lacked persistency in the matter of consistent forward movement which seemed to characterize the controls. There was a greater tendency for them to retrace and return to the point of entrance during the early trials. The curves show that increased amounts of smoking also increased this tendency to retrace. The controls tended to push forward to the goal with comparatively less hesitation and fluctuation of movement during the early trials than was characteristic of the experimentals. The net result was that the experimentals, by many retracings of portions of the maze, tended to mass their learning and thus cut down somewhat the average of the number of trials necessary to complete the learning. The larger significance of this procedure for efficiency and relative ability in learning is not clear.

The best representation of this retracing tendency may be seen in the number of B-type errors that were amassed. The errors that were recorded were of two types: (1) the ordinary cul de sac errors designated as A-type errors, and (2) straight retracings of the true pathway, designated as B-type, an error being counted whenever the rat turned a corner while moving towards the point of entrance. A U-turn around a cul de sac was recorded as one error. The total of the B-type errors for a rat or a group gives a fairly reliable index of the number of times the maze, or portions of it, was traversed in excess of the number of times indicated in the number of recorded trials. It is to be remembered that each retracing implies an equal distance to be recovered by the rat. Therefore, the number of these errors should be doubled in order to estimate the average number of times the maze was traversed both forwards and backwards. There was, of course, no way of telling what portion of the straight segment was retraced, but it is probable that the frequent retracings of segments which were not counted as errors would more than justify the procedure of reckoning each error as a full retracing for comparative purposes. A total of eighteen such errors would be made in making a complete circuit of the maze from the food-box back to the point of entrance.

Taking all the B-type errors for the CI group exclusive of those amassed during the initial trial, the thirty-five made a total of 1364 or an average of thirty-nine. This was equivalent to 4.3 traversals of the maze in addition to those indicated in the twenty-one trials which was the average of the group. (See table XVII.) The twenty-eight members of the EII group amassed a total of 1680 such errors for an average of sixty. This was equivalent to about seven traversals of the maze in addition to those indicated in the 18.6 trials which was the average of the group. Thus it is seen that the EII group, by making 35 per cent more B-type errors than their controls, effected a saving in average trials of 11.4 per cent. The EIIb group also averaged fifty-nine such errors, but they reduced their average trials to 16.9.

This same tendency to retrace and mass their learning was seen in the case of the EI group in comparison with their controls the CII group. A comparison of the B-type errors for all trials exclusive of the first showed but a slight difference between the groups. But when those for the initial trials were added, the CII group were found to average fifty-two such errors while their litter-mates, the EI group, averaged sixty-one, a difference in favor of the CII group of 14.75 per cent. On the other hand, the EI group learned with an average of 10.8 per cent less trials than the CII group.

The above comparisons are sufficient to indicate a well-marked tendency produced by the experimental factor of tobacco smoke. They also reveal the fact that the number of trials is not a very accurate index of the number of times a rat traversed the maze. The records show that some rats which took as many as twenty-five trials to complete their learning were able, by moving steadily forward in each trial, to keep their learning time and number of errors proportionately low. Others learned in ten or twelve trials, but by repeatedly retracing they consumed much time and amassed a relatively large number of errors. A study of the original data sheets reveals the fact that the retracings characterized the first part of the learning series rather than the last. Figure 11 shows that the experimental groups averaged higher than the controls in errors for the first stage of the learning; figure 12 shows the same situation but for the guided runs instead. A large proportion of these errors were of the B-type.

It seems clear that there was a significant element in the procedure which indicated something as to the relative learning ability of the groups. Those that spent much time in the maze during the early trials and repeatedly retraced thereby tended to mass their learning.

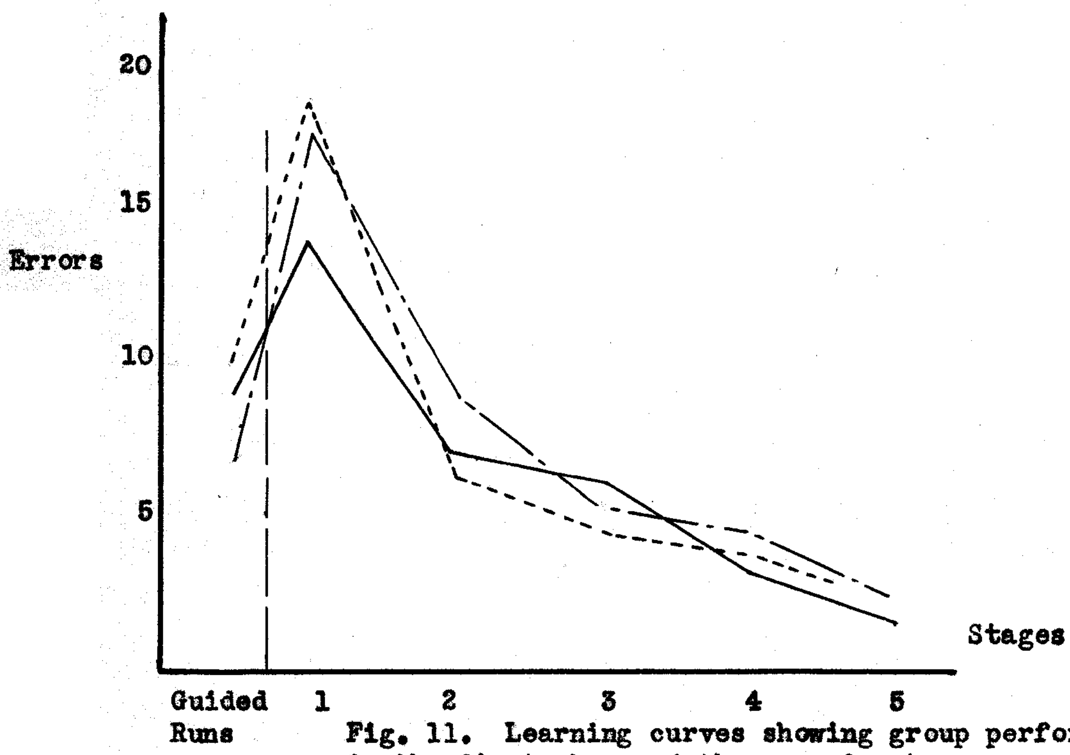
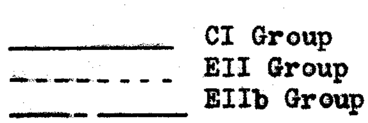


Fig. 11. Learning curves showing group performances in the first phase of the experiment.



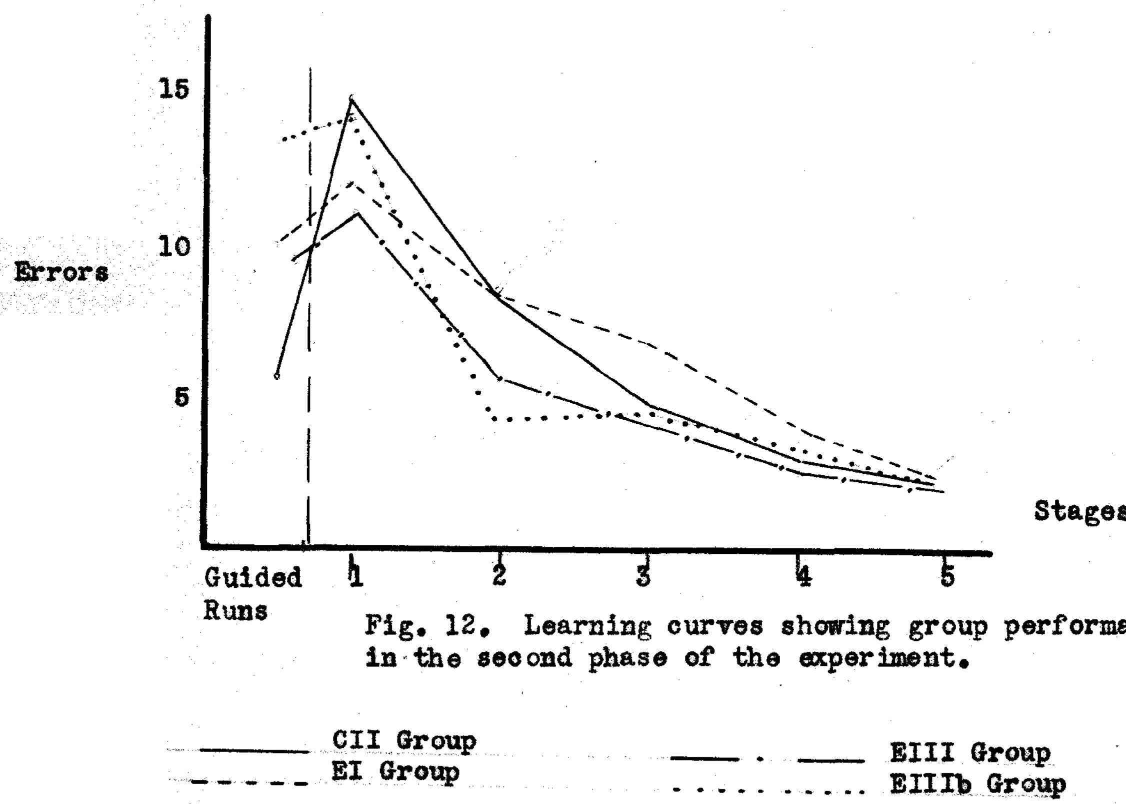


Fig. 12. Learning curves showing group performances in the second phase of the experiment.

In this manner they materially reduced the number of practice periods necessary for their learning. But if there is a potent time element in learning as expressed in Jost's Law (28:291), which implies a gradual fixation of new functional nervous connections, then the difference becomes apparent. If the process of fixation is gradual, then the advantage was definitely with those that took the larger number of trials. Therefore, those rats which learned with a lesser number of trials but with equal time and errors should, in the light of this law, be regarded as definitely superior to the others.

2. Variability in exploratory movements. - As the lack of consistent forward movement tended to reduce the average number of trials necessary for completion of learning by the experimentals, so a corresponding lack of exploratory movements tended to reduce their average learning time. Normal rats evidence great curiosity in their behavior. They must be desperately hungry to be thwarted from their natural tendency to investigate completely every new situation. When the control rats were first placed in the food box of the maze to begin their period of preparation for their maze learning, they spent the most of their time in racing about on top of the maze in purely exploratory movements. They ran to the food box occasionally for a few bites of food, but soon they were out again vigorously investigating everything.

This same tendency was strong when they came to run the maze. They were obviously very hungry and their main incentive was to get to the food box, yet it was plainly evident that the other incentive to explore was playing a powerful role. During the first six or eight trials, the experimenter had to be very quick in slipping the panel into place behind the rat after he entered the food box, otherwise he would dark back into the maze and renew his explorations. It was characteristic of them, after they had taken a bite or two at the close of a run, to leap out of the food box and explore the top of the maze anew. This was freely permitted, for it was considered that the incentive to escape from the narrow confines of the maze alley-way might greatly augment the other incentive to reach food, thus assuring a greater degree of effort on the part of the rat to get through.

It was plainly different with the experimental rats. They were obviously lacking to a considerable degree in these exploratory move-ments. Their major incentive seemed to be to reach the food box and they were not swerved from this to the degree that was characteristic of the controls. It was rarely necessary to use the panel to block their return into the maze and seldom did any leave the food box to explore the top.

This apparent singleness of purpose, together with a more highly stimulated physical condition which seemed to result from the smoking, resulted in better time and trial averages for the five gram rats. Perhaps this increased efficiency in learning may have been due to (1) a loss of incentive to normal exploratory movements thus making possible very methodical and highly directed efforts to reach the goal; or (2) the fact that the effects of tobacco smoke may be correlated in some way with a reduction of synaptic resistance and increased ease of spread of nerve impulses thus facilitating learning, as suggested by

Lashley (16) in accounting for the superiority of his strychninized rats in a learning situation.

3. Differential effects resulting from varied amounts of smoking.- A significant result of the experiment indicated that there were differential effects resulting from varied amounts of smoking. The EIIb and the EIIIb groups were smoked with fumes from ten and twenty grams of tobacco for periods of one hour and three hours respectively. Their behavior and the records which they made indicated that the point of maximum stimulation had been passed and the larger amounts of smoke acted as a depressant. Reference to Table XVI shows the extent of the retardation.

A comparison of two groups of third generation experimentals gives the best representation of the significant variations from normal learning behavior resulting from nicotinism. Two groups of siblings, the EIII and the EIIIb, represented very extreme reactions to the tobacco smoke. The EIII group, which was composed of the first litters of the EII group breeders and fumed with smoke from five grams of tobacco, probably showed maximum effects of stimulation. While they were much the smallest of all in body size and weight, their movement in the maze averaged the fastest (see page 79), and they far surpassed all others in mean learning time and in average errors amassed. By far the best individual records were made by members of this group. One male, for instance, made only twelve errors and learned in 151 seconds. (See the appendix for individual records.)

The EIIIb group was composed of the second litters of the EII group breeders. Their records show an opposite effect of the smoking process. They were fumed with smoke from twenty grams of tobacco, being left in the smoker about eight hours each day. The smoke gradually escaped from the smoker, but the total time in which they were subjected to heavy inhalations aggregated about three hours daily. The tobacco was not all burned at once but three periods of fuming were interspersed throughout the day. The apparent effects of the increased smoking was to make them dull and listless. When they were first placed in the food box of the maze they went stolidly at their feeding and then all except one male curled up around the food container and went to sleep. This one male did explore the top of the maze in rather normal fashion. But the behavior of the group as a whole throughout the entire learning period was similarly indifferent and listless.

Effect of Tobacco Smoke Upon Sex Differences in Learning

An interesting disclosure of the experiment was seen in the fact that the males were generally more consistent and uniform in their maze performance than the females. It seemed to be more characteristic of the females to retrace frequently. The result was that their errors and mean learning time were higher. Their actions probably tended to mass their learning which resulted in cutting down somewhat the average number of trials. Table XVIII gives a comparison of the males and females in the various groups.

The character of the sex differences in maze learning may be seen in a comparison of groups A and B in the table. These were the normal males and females representing two generations of rats. It

TABLE XVIII

A COMPARISON OF MALES AND FEMALES IN THE VARIOUS GROUPS, SHOWING THE EFFECTS OF SMOKING UPON SEX DIFFERENCES

Group	Mean Trials	M.D.	Mean Time	M.D.	Mean Errors	M.D.
A. CI and CII Males	20.4	6.5	636	207	107	34
B. CI and CII Females	19.8	4.2	730	285	123	37
C. EI, EII, and EIII Males	17.6	4.2	566	208	104	26
D. EI, EII, and EIII Females	17.4	4.6	572	314	115	45
E. EIIb and EIIIb Males	21	4.3	887	206	139.5	34
F. EIIb and EIIIb Females	18	3.9	940	402	127	34

was generally easier to predict what the males would do for they were more consistent and constant in their action than the females. They could usually be counted on to press steadily forward to the goal. The females were more vacillating in their behavior, as may be seen in a comparison of the mean learning time and the mean errors for the two groups. The males with an average learning time of 636 seconds surpassed the females by 12.9 per cent. They were 13 per cent superior to the females in average of errors. The mean variability of the females with respect to their average time was 27.2 per cent greater than that for the males; for errors they were 2 per cent more variable. These differences may be regarded as indicating interesting and significant trends for all the groups that were tested.

A comparison of the records of groups C and D with groups A and B sheds light on the question of the effect of tobacco smoke upon sex differences. These groups represent the three generations of rats that were fumed with smoke from five grams of tobacco. Here again there is a very slight advantage for the females in the average number of trials. But for mean learning time, the normal relationship between males and females as established by two groups of normal rats was decidedly altered. Instead of there being a difference of nearly 15 per cent, it has dropped to slightly more than 1 per cent; the average of the errors for the female groups was 9.6 per cent higher than for the males instead of 13 per cent as for the control groups. In the matter of variability, these experimental females were 33.7 per cent more variable than the males with respect to average time, and 40.7 per cent more variable with respect to mean errors.

To get at these sex differences from a different angle and further show the differential effects of tobacco smoke upon males and females, some inter-group relationships and comparisons are very suggestive. (See table XIX.)

Comparing group A with group C, which means a comparison of all normal males with all experimental males fumed with smoke from five grams of tobacco, the experimental males are seen to be superior to the control males in all three criteria of learning. They needed 13.7 per cent fewer trials to complete their learning, their average time was 11 per cent less, and they made an average of 2.8 fewer errors. In comparing the variability of the two groups, the experimentals are seen to be more consistent in their group performance than

TABLE XIX

INTER-GROUP COMPARISONS OF MALES WITH MALES AND FEMALES WITH FEMALES TO SHOW EFFECTS OF TOBACCO SMOKE ON LEARNING

Group	Mean Trials	M.D.	Mean Time	M.D.	Mean Errors	M.D.
A. (24) CI and CII Males	20.4	6.5	636	207	107	34
C. (42) EI, EII, EIII Males	17.6	4.2	566	208	104	26
B. (32) CI and CII Females	19.8	4.2	730	285	123	37
D. (40) EI, EII, EIII Females	17.4	4.6	572	314	115	45

the controls in two of the criteria.

In like manner, comparing the B and D groups, which were all the normal females and the experimental females that were smoked with fumes from five grams of tobacco, the differences are most interesting and suggestive. It is thus seen that the experimental females required 12 per cent less trials, they learned in 21.6 per cent less time, and they made 6.5 per cent less errors. Their degree of variability, however, was greatly increased. The experimental females were 9.2 per cent more variable than the controls in time, and in errors they were 15.7 per cent more variable.

The evidence from these comparisons indicates that tobacco smoke in limited amounts received in daily inhalations affected learning activities favorably; and that females were more affected by it than the males. Both groups showed considerable improvement in the different criteria, particularly in that of learning time. This may register an increase in speed primarily, resulting from purely physical stimulation. While the variability of the male groups was not increased by the inhalations of tobacco smoke, that of the females was materially increased.

Effects of Tobacco Smoke Upon Rate of Movement in the Maze

One of the obvious effects of the smoking process was to produce rather significant variability in gross physical activity. While it was not the province of the experiment primarily to study this aspect of the problem, yet the following practical observations may bear some significance.

The effect of the fumes from the standard amount of tobacco (five grams) seemed to be to produce an increase of activity. This was discernible in casually observing the two groups in their normal behavior in their cages. The smoked rats seemed to be more restless and active. This practical observation is confirmed by Nice in his experiment with white mice (20:II). His smoked mice measured much greater activity in their revolving cage than did the normals.

The effect of this stimulation was clearly seen in the maze running. The smoked rats were noticeably more aggressive and they ran faster. It has been possible to measure that difference with some degree of precision. By taking the errorless runs of each group, which constituted the criterion of learning, that is, the last four, it was possible to compare rather accurately the rate of movement of the different groups in this respect.

The average time for the errorless runs of two groups of controls totaling fifty-six rats was fourteen seconds. Three groups of experimental rats totaling eighty-two which were fumed with smoke from five grams of tobacco averaged 12.7 seconds for their last errorless runs. This average was 9.3 per cent better than that of the controls. Of the three groups of experimentals, those representing the third generation (EIII) made much the best average. Thirty-one of these averaged eleven seconds for their runs, which represented an average speed 21 per cent greater than that of the controls.

But the stimulating effects seemed to obtain for only a limited amount of smoke. Beyond that amount the smoke acted as a physical depressant. Those that were fumed for longer periods of time and with larger amounts were rather listless and somewhat sluggish in their movements. Two groups, the EIIb and the EIIIb, were fumed with smoke from ten and twenty grams of tobacco respectively and for longer periods of time. Their average time for the four runs was 16.4 seconds, which was an average 14.6 per cent higher than that of the controls and 22.6 per cent higher than that of the five gram rats.

Summary

1. Rats that were fumed with smoke from five grams of tobacco excelled both the rats that were not fumed at all and rats that were fumed with larger amounts, in all three criteria of the maze learning.

2. Those that were fumed with smoke from ten and twenty grams of tobacco were inferior to their controls in two of the criteria of learning, i.e., learning time and errors.

3. Fumed rats tended to retrace the maze pathway more often than the controls.

4. The smoking process effected a lessening of exploratory

movements on the part of the experimental rats.

5. Normal male rats were found to be generally superior to the normal females in learning ability.

6. Differences in learning ability between males and females tended to disappear after fuming.

7. The female groups were found to be more variable than the males. Tobacco smoke increased the variability of the female groups without affecting the males proportionately.

8. Rats fumed with smoke from five grams of tobacco tended to run faster in the maze than the others.

9. The movement in the maze of those that were fumed with smoke from ten and twenty grams of tobacco was slower than for the other groups.

CHAPTER V

SUMMARY AND CONCLUSIONS

One of the perplexing questions that has been awaiting an answer for a long time is concerned with the effects of tobacco smoke upon the mental processes. It is clear that the maze experiment cannot be made to tell all that might become known concerning this problem. Maze learning is primarily of the type designated as motor learning. As such, its measures are too crude and unrefined to throw much light upon some of the subtler processes that are involved in learning and which ought to be measured. To be sure, there are unmistakable evidences of perceptual and ideational learning involved in maze learning; the latter types embracing such important factors as insight, memory, imagination, conception, judgment and reasoning. It is with these elements that popular opinion is most concerned, but the maze has so many purely physical and mechanical elements in it that it is very uncertain to what degree it measures these higher mental processes.

The maze in animal experimentation can do little more than give an answer in a very general way regarding the problem of the relative learning ability of two or more groups. The significance of such results may be much or little; the degree of that significance may not be determined until psychologists have solved some of the problems inherent within the maze experiment itself. However, any experimental results that tend to show that tobacco smoke does affect the rate of learning cannot fail to be of interest and to possess scientific value.

The major results of this experiment are concerned with two aspects of the tobacco problem: (1) the effect of tobacco smoke upon the physical organism, and (2) the effect of tobacco smoke upon the rate of learning. A recapitulation of the summaries of those results follows.

A. Some physical effects of tobacco smoke.-

1. Rats that were fumed with smoke from five grams of tobacco for a period of seventy-five to ninety days were found to be 19 per cent more prolific than the normal rats.

2. Prolonged smoking of those same rats resulted in reducing the average size of their second litters 50 per cent. This average was 35 per cent less than that of the normal rats.

3. The viability of the third generation was greatly reduced, especially among the second-litter rats.

4. The fertility of the third generation breeders was 60 per cent less than that of the controls, and 67.6 per cent less than that of the previous experimental groups. Moreover, there were three out of eight third generation females that failed to reproduce.

5. The viability of the fourth generation was greatly reduced, only 17.6 per cent of them surviving.

6. Tobacco smoke retarded the growth of the rats. The first generation experimentals averaged 8.13 per cent lighter than their controls after four weeks of smoking.

7. The second generation experimentals averaged 11 per cent lighter than their controls at five weeks of age and 15 per cent lighter at nine weeks.

8. The third generation experimentals averaged 31 per cent lighter than the controls at five weeks of age and 37 per cent lighter at nine weeks.

9. The stunting effects of tobacco smoke were transmitted to progeny. The three surviving young of the fourth generation were never smoked, but at forty days of age two of them averaged 21.7 per cent less in weight than the controls. Another was 23 per cent lighter than the controls at thirty-three days of age.

10. Normal rats tended to make a more prolonged and larger growth development than those that were smoked.

B. Effect of tobacco smoke upon rate of learning.-

1. Rats that were fumed with smoke from five grams of tobacco excelled both the rats that were not fumed at all and rats that were fumed with larger amounts, in all three criteria of the maze learning.

2. Those that were fumed with smoke from ten and twenty grams of tobacco were inferior to their controls in two of the criteria of learning, i.e., learning time and errors.

3. Fumed rats tended to retrace the maze pathway more often than the controls.

4. The smoking process effected a lessening of exploratory movements on the part of the experimental rats.

5. Normal male rats were found to be generally superior to the normal females in learning ability.

6. Differences in learning ability between males and females tended to disappear after fuming.

7. The female groups were found to be more variable than the males. Tobacco smoke increased the variability of the female groups

without affecting the males proportionately.

8. Rats fumed with smoke from five grams of tobacco tended to run faster in the maze than the others.

9. The movement in the maze of those that were fumed with smoke from ten and twenty grams of tobacco was slower than for the other groups.

Meaning of the Results

Medical opinion seems to have established the fact that nicotine affects very definitely the autonomic nervous system. If that is the case, the normal functioning of the ductless glands would probably be disturbed.

The behavior of the rats under the influence of nicotine in the present experiment was very similar to that resulting from the feeding of thyroid extract as noted by Shippen. She found that the thyroid extract materially reduced the weight of the rats and accelerated their learning. Her explanation of the results is as follows:

> Thyroid-fed rats have been found by other experimenters to require more food than normal rats, as their increased metabolism plus greater activity, consume more nourishment. Thus the tendency of the thyroid-fed rats to be superior to the controls can be explained by hyperactivity plus stronger motivation, rather than by any change in the physical makeup of the nervous system. (24:72-73)

She found that small amounts of thyroid served to exhilarative rats, thus aiding their learning, whereas larger amounts caused sickness which seriously interfered with their learning ability. This is in substantial agreement with the results of the present experiment. The behavior of the smoked rats seemed to clearly point to a condition similar to hyperthyroidism.

To what extent other ductless glands may have been involved is of course problematical. The variations in fertility resulting from the smoking process may, however, point to some effect upon the pituitary body and the gonads. It seems reasonable to suppose that the obtained results were attributable to some disturbance involving the autacoid-producing glands.

The educational implications of this study are indirect and inferential. In the first place, there is no certainty that tobacco smoke affects humans and rats alike. On the other hand, there seems to be a wide-spread feeling among educators that tobacco addiction on the part of growing children does affect their learning behavior. It is reasonable to suppose that the more highly organized nervous systems of humans would not be less susceptible to the effects of narcotics than those of animals.

At all events, educators cannot be indifferent to anything which holds a threat of violence against the emotive or learning behavior of children. If nicotinism attacks the autonomic nervous system, then its disturbance of the normal functioning of the endocrine glands may be expected to have pronounced repercussions in the emotive behavior of children. It may be that the irregular conduct which is so often associated with the use of tobacco on the part of growing boys is in large part directly traceable to the irregular functioning of the "kinetic drive."

It is probably true that scientific experimentation has demonstrated the fact that the use of tobacco is not to be compared in its effects with the use of alcohol or other narcotics. But research

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APPENDIX

SUMMARY OF INDIVIDUAL RECORDS

Set	Rat	Trials	Seconds	Errors
CI-1	M1	25	899	121
	M2	20	1158	101
	M3	16	514	52
	F1	16	1022	126
CI-2	M1	12	565	86
	M2	18	568	104
	M3	16	515	104
	F1	21	1020	178
	F2	15	483	108
	F3	17	444	81
	F4	17	687	115
	F5	18	488	91
	F6	21	634	68
CI-3	M1	28	815	142
	M2	17	732	142
	M3	25	651	94
	F2	19	1392	200
	F3	31	1221	166
	F4	18	823	87
	F5	16	567	85
	F6	18	914	155

Set	Rat	Trials	Seconds	Errors
CI-4	M1	4545	1857	158
	M2	27	986	189
	M3	20	511	73
	M4	32	1097	126
	F1	20	1516	144
	F2	17	595	92
	F3	29	1098	127
	F4	28	661	94
	F5	27	838	122
	F6	9	384	76
CI-5	M1	17	545	92
	M4	15	438	89
	F1	21	1106	168
	F2	21	1217	167
CII-1	M2	11	231	24
	F1	15	452	79
	F3	26	1146	183
	F4	13	505	86
CII-2	M1	7	367	46
	M4	13	816	161
	F2	19	1043	218
	F3	16	411	85

Set	Rat	Trials	Seconds	Errors
CII-3	M2	32	1031	162
	M3	24	756	94
	F1	20	678	140
	F4	15	823	146
CII-4	F2	28	1181	181
	F3	31	942	157
CII-5	M1	17	776	145
	M2	26	892	134
	M3	16	592	62
CII-6	M1	12	905	74
	F2	18	565	46
	F3	17	924	82
	F4	15	1094	101
EI-1	M2	10	397	66
	M3	20	562	83
	M4	20	593	85
	F1	25	1325	234
	F4	12	402	51
EI-2	M2	20	940	135
	M3	18	536	103
	M4	12	385	65
	F1	15	595	122

Set	Rat	Trials	Seconds	Errors
EI-3	M2	24	873	155
	F3	17	699	163
EI-4	M4	18	637	73
	F1	13	553	106
	F2	10	639	115
	F3	11	300	50
EI-5	M1	11	686	116
	M3	18	976	153
	M4	21	713	71
	F2	22	777	147
EI-6	F1	17	841	166
	F2	17	469	54
	F3	13	1154	207
	F4	10	393	59
EII-1	M1	16	848	140
	M2	18	840	140
	M3	29	888	116
	M4	15	639	105
	M5	15	709	84
	M6	24	716	114
	M7	28	1386	124
	M8	12	277	46
	F1	14	1677	169
	F2	18	649	118

Set	Rat	Trials	Seconds	Errors
BII-2	M1	20	732	158
	M2	22	964	167
	M3	15	685	126
	M4	18	820	117
	M5	24	712	156
	M6	19	594	152
	F1	20	1328	213
	F2	16	1153	137
	F3	13	1366	128
	F4	17	1598	193
	F5	29	1430	214
BII-3	M1	18	965	135
	F1	12	568	85
	F2	15	485	63
	F3	24	1298	139
	F4	12	648	99
	F5	20	588	111
	F6	19	674	117
BIII-1	M1	11	449	77
	M2	14	382	77
	M3	16	668	91
	F1	12	394	75
	F2	8	216	28

Set	Rat	Trials	Seconds	Errors
EIII-2	M1	15	745	111
	M2	15	485	103
	F1	22	425	65
	F2	19	445	55
	F3	17	515	41
	F4	32	579	93
	F5	18	511	85
	F6	15	512	57
	F7	24	756	165
	F8	21	456	81
EIII-3	M1	21	1141	115
	M2	16	795	125
	M3	11	318	64
	M4	20	846	114
	M5	12	627	62
	F1	20	1694	179
	F2	25	632	127
EIII-4	M1	39	657	107
	M2	14	309	66
	M3	8	151	12
	M4	17	442	104
	M5	18	542	106
	M6	11	664	86

Set	Rat	Trials	Seconds	Errors
BIII-4	F1	8	255	27
	F2	24	563	108
	F3	12	984	153
BIIb-1	M1	25	1255	248
	M2	21	681	93
	M3	16	854	123
	M4	12	757	155
	F1	12	1229	139
	F2	17	637	130
	F3	18	714	78
	F4	15	580	100
	F5	21	1001	138
BIIIb-1	M1	23	823	89
	F1	18	1723	140
BIIIb-2	M1	16	741	108
	M2	21	1547	154
	F1	31	1525	193
	F2	16	559	79
BIIIb-3	M3	30	925	138
	F1	16	1724	189
	F2	22	1210	154
	F4	14	1319	88