THE EFFECT OF TEMPERATURE CHANGES ON THE BEHAVIOR OF THE WHITE RAT

by

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CHAPTER I

INTRODUCTION

History and General Background

In the last few decades there has been an increasing recognition that man's behavior cannot be understood in terms of any single isolated group of conditioning factors. On the one hand, emphasis has been placed upon evaluation of the biological needs and drives which form the basic foundation for man's complex activities. On the other hand, there has been an emphasis on the social and cultural patterns of which man is a part, and on their importance in determining certain aspects of his behavior. The present emphasis upon what many, for the lack of a better term, call the biosocio-psychological sphere is indicative of a growing awareness that a wide range of influences must be considered today in the study of human behavior.

Müller-Frienfels, (51) for example, in his recent book, "The Evolution of Modern Psychology", points out clearly how attempts to understand man in terms of one or two or even three elementary causal categories have failed, and outlines some of the methods used to secure a broader frame of reference. He uses such terms as psycho-sociology, biopsychosociology, and sociopsychology and speaks of the "super-individual" aspects of behavior. All such evaluations, it seems, are efforts to go beyond the more limited frames of reference of the earlier psychologies, and to clarify the interrelations between important biological, social, and cultural forces and man's behavior.

Developing as a part of this method of approach has been the effort to show the importance to human behavior of purely environmental forces. To be sure, in many instances this movement turned into the task of demonstrating that only environmental forces were important in the development and production of behavior. The rather onesided view that all behavior was environmentally determined was obviously inadequate, and led to reaction, skepticism and untimely prejudice.

Within the past few years there has developed, in a number of sciences, the conviction that the total pattern of forces acting upon the organism must be considered if an adequate understanding of behavior is to be obtained. It is not the place or purpose of the present introduction to survey exhaustively the development of this trend. As with any such trend, a study of history will indicate that there have been some approaches to this general systematic position. The question, Where and how have they failed to arrive at the conclusions reached today? must be left to other studies.

The details of these current points of view differ from one science to the other. An outstanding characteristic, however, has been the insistence that only when the configuration or pattern of forces acting upon the organism is known can there be developed an adequate picture of man's behavior. To this end, many general fields of influence hitherto not seriously considered are being studied and the relation clarified between these changes and the general pattern of behavior.

Prominent among these newer approaches we find an increasing recognition of the influence of climatic changes. While there has been much speculation as to the possible relation of climate to changes in human behavior, there have been few attempts to attack this problem in a truly comprehensive manner. The organismic point of view, it would seem, offers the possibility of examining these influences in their proper relation to other important environmental forces. Cultural, psychological, and physiological adaptations to different climatic conditions no doubt take place. Yet man responds to cultural, economic and political influences, within the pattern of human behavior itself. The organismic point of view suggest_ that these latter influences are integrated with environmental conditions. Moreover, in this view, the reciprocal relations between the organism and environment are emphasized. The organism-in-the-environment is the fundamental unit, and the action of the organism in changing, selecting, and reacting to the environment is as important as the action of the environment upon the organism.

In the present introduction only a glimpse can be obtained of the many studies of human behavior, made in the past, that have recognized the importance of environmental and climatic factors in addition to the purely cultural. A survey of environmental theories of society by Franklin Thomas (66) gives a fairly complete history of these studies. Omitting the more speculative attempts, for many have been little more than that, only three are of interest here, those of Bodin, Montesquieu, and Buckle. All three were interested in describing general laws governing the development of civilizations and nations, and concluded that climatic influences must be taken into account.

Bodin's (11) was the first serious attempt to evaluate the influence of geographic environment and climatic changes upon the evolution of society. As Thomas (66) points out, Bodin tried to find general laws for the guidance of statesmen. Quoting Thomas:

> "In the latter work (Commonwealth) under the caption 'What order and course is to be taken to apply the form of a Commonwealth to the diversities of men's humours, and the means how to discover the nature and disposition of the people,' he (Bodin) says that the failure of statesmen to take into consideration the character of the population in forming laws has often led to trouble and even the downfall of the states. Further on he asserts that historians and philosophers of all time have called attention to great

differences in population from the effect of climate and location. 'Therefore a wise governor of any Commonwealth must know their humours before he attempts anything in the alteration of the state and laws. For one of the greatest, and it may be the chiefest foundation of a Commonwealth is to accomodate the state to the humour of the citizens, and the laws and ordinances to the nature of the place, persons, and time'." (p. 49)

Although Bodin did little more than restate some of the earlier conclusions concerning the influence of climatic changes upon behavior, and although he was extremely mystical in some of his ideas, yet his recognition of the problem is an important one for the statesmen as an historical landmark.

Montesquieu's (48) purpose was much the same in his Spirit of the Laws. He too believed that the nature of the population should be considered by the statesmen and that statute laws should be adapted to the general character of the people. The following quotation indicates some of the factors he felt to be important:

"They (laws) should be in relation to the nature and principle of each government whether they form it, as may be said of political laws; or whether they support it as may be said of civil institutions.

They should be in relation to the climate of each country, to the quality of the soil, to its situation and extent, to the principle occupation of the natives, whether husbandmen, herdsmen or shepards; they should have relation to the degree of liberty which the constitution will bear; to the religion of the inhabitants, to their inclinations, riches, numbers, commerce, manners and customs. In fine, they have relations to each other, as also to their origin, to the intent of the legislator, and to the order of things on which they were established; in all of which different lights they ought to be considered.

This is what I have undertaken in the following work.

These relations I shall examine since all these together constitute what I call the "Spirit of the Laws"." (Vol. I, page 7)

The historian, Buckle (14), in his attempt to state the general laws which govern the course of human progress, treated climate, soil, food and other aspects of nature as important influences in the character and destiny of nations. As Thomas (66) points out:

"There is no question, of his belief in direct climatic influences, distinct from the bounty of nature. He held that in the early history of a people the accumulation of wealth depends upon two things--the energy and regularity with which labor is applied, and the returns made to that labor by the bounty of nature. The energy and regularity of the labor in turn depends upon the climate.------The only effective progress depends upon the energy of man, and the powers of man are not limited like those of nature. Climate reacts upon man, stimulating his energy and developing his powers. Therefore, that civilization conditioned by the development of human energy is bound to outstrip those which depend mainly upon nature alone and do not call forth the latent powers of man." (page 88)

We find somewhat the same pattern of thought in present day writings. J. W. Bews (9), in his book, Human Ecology expresses the fundamental aims and purposes of the ecological approach to the study of human behavior. He best preserves a balance between the relative importance of the organism and environment characteristic of the organismic approach. As can be seen from the following quotations, his aim is no less ambitious than that of any of the three studies just mentioned. Ecology is for him the means of systematizing all human behavior. In his introduction he says:

"The first all-important fact, on which the greatest possible emphasis must be laid, is that life apart from the environment does not exist, and cannot be conceived. Life consists essentially of a process of interchange between the life-substance or protoplasm and the environment. At the same time, the term environment apart from life is, of course, meaningless.

The interchange between the living protoplasm and the environment represents the working of the living machine. When this working ceases the organism dies. It no longer functions. Whether it can ever temporarily altogether cease functioning and afterwards recommence, without dying, is perhaps a point that might be debated, though hardly at the present stage of our discussion. It may be remarked, however, that, even in the case of the resting seeds or spores of plants, the evidence available goes to show that the life changes are still continuing during the resting period, though at a very slow rate. Changes in the rate of functioning are obviously continually taking place, yet while life goes on, the functional relationship between environment and organism remains. Environment, function, and organism constitute what has been called the fundamental biological triad. The triad must be studied as one complete whole, and this study is essentially what we mean by ecology.

The importance of a holistic approach to the study of ecology can scarcely be over-emphasized. Various biological workers from time to time have tended to lay emphasis now on the environment, now on function, and now on the organism itself. All such studies are important, since they contribute to the proper understanding of the triad as a whole, but it is the task of the ecologist to preserve a true balance. In the earlier stages of its development, and even still to some extent, ecology has perhaps tended to lay too much stress on the first term of the triad. The environment certainly does profoundly affect the organism's structure and behavior, but it must always be remembered that the functional relationship between environment and organism is a reciprocal one. The organism also continuously influences the environment." (page 1-2)

He sums up his conception of the study of ecology in the following words:

"As we look back over the whole field of ecology we see that not only is it concerned with a study, made as well-balanced as possible, of the threefold nature of life (environment--function--organism), but it also has three different aspects of its own. First of all ecology is a science, with its own special technique, by which, like every other science, it analyses and investigates the phenomena of Nature. In the second place ecology has a very comprehensive view-point of its own, so that it may be regarded as a philosophy. After all every single philosophy, in essence, is merely this--a view-point, a special way of looking at things, a special way of regarding the ultimate reality of life and nature--and this applies equally to the subject of ecology. In the third place ecology is to be looked upon as an art. It has much in common with the art of architecture. It provides a plan, a pattern into which can be fitted everything that we know of man, his responses, his activities, and his words. In brief, as it has been our aim to show throughout, ecology endeavors to understand how and why man is as he is and how and why he behaves as he does." (pages 299-300)

Lewis Mumford (52) (53), although interested primarily in tracing the interrelations between the development of the machine and urban life with other aspects of the cultural pattern, expresses very similar ideas. In his book, <u>The Culture of Cities</u>, he says:

"The autonomy of the organism, so characteristic of its growth, renewal, and repair, does not lead to isolation in either time or space. On the contrary, every living creature is part of the general web of life; only as life exists in all its processes and realities, from the action of the bacteria upward, can any particular unit of it continue to exist. As our knowledge of the organism has grown, the importance of the environment as a co-operative factor in its development has become clearer; and its bearing upon the development of human societies has become plainer, too. If there are favorable habitats and favorable forms of association for animals and plants, as ecology demonstrates, why not for men? If each particular natural environment has its own balance, is there not perhaps an equivalent of this in culture? Organism, their functions, their environments: people, their occupations, their workplaces and living-places, form interrelated and definable wholes.

Such questions as yet can evoke only tentative answers; but they provide a new starting point for investigation.---" (pages 300-302)

More closely related to the present study is the approach recently begun by R. H. Wheeler. Wheeler concludes that complex and comprehensive behavior patterns, even to points of view in science, are found which are related in a striking fashion to relatively long time climatic changes. Man's behavior must be considered as a function not only of individual and social forces, but of all aspects of the environment. To explain behavior, the interrelation of the organism and all aspects of the environment to which it responds that must be taken into account. Since climatic changes seemed to be an especially important aspect of environment, Wheeler made an extensive study of the history of climate. All evidence pointed to the existence of shifts in prevailing climatic conditions over large areas of the earth. These were of the same general nature, and were found to occur so nearly at the same time that they can be regarded as world-wide in extent. Wheeler (74) points out that the shifts of moderate length but of irregular periodicities, have the following general characteristics:

"The usual cycle passes through the following stages; (a) a cold-dry maximum; (b) recovery of temperature ahead of rainfall, hence a short, warm termination of a cold, drought era; (c) a striking warm-wet maximum (which, if long enough, has a strong cold-wet break or "saddle") turning to (d) hot and dry. Then, on a falling temperature curve, rainfall undergoes a secondary recovery, resulting in a fairly marked cold-wet phase as a warm epoch shifts to cold. Then it becomes dry again, and the cycle is repeated." (page 231)

Wheeler also emphasizes that man's behavior must be considered as a function of the total field of energy. "An active climatic environment is conducive to cultural activity." The effect of the active environment is felt in a wide range of man's activities. The following quotation outlines many of these aspects:

"A culture pattern, or behavior pattern of human beings in social groups, has consistently shifted from an emphasis on one set of variables to its opposite along with shifts from cold-dry to warm-wet maxima. Some 250 of these variables have been studied and more are constantly being added. Democratic, republican, and "romantic" epochs fall on the cold side, while socialistic, totalitarian, and "classical" epochs fall on the warm side. The mentality of classical, warm periods is much more profound than that of cold periods, as measured by philosophy, science, art, and literature. These are periods when culture is dominated by a wealthy aristocracy. Cold periods are dominated by a democratically minded middle class of more humble, but no less important, achievements. Warm periods are organic; cold periods, atomistic. The warm are idealistic, the cold, utilitarian; the former, rational, the latter, empirical; the former, "time minded", the latter, "space minded".

The profound psychological differences between these two patterns cannot be understood except in terms of the same sort of energy behavior that characterizes the climatic such as storms, earthquakes, and volcanoes. When his environment is more active, so is man; when activity declines in his environment, man's own energy is at a low ebb. Man's most profound cultural achievements have occurred during transition periods from cold-dry to warm-wet maxima and back again, i.e., about the axis of the curve when visualized in the form of a wave. The maxima of the wave, both positive and negative, are "static" or "dead" periods, environmentally and culturally." (page 232)

All three of the approaches just mentioned, Bews, Mumford and Wheeler emphasize essentially the same thing. It is impossible to study and understand human behavior without considering the total field of forces operating to produce that behavior. Included in this field of forces are not only the biological needs and predispositions, intellectual and emotional modes of adjustment, but also the social, cultural and physical aspects of the environment. Bodin, Montesquieu, and Buckle also were attempting in a relatively crude method to consider such relations. Bews has called this the ecological approach, consciously widening that concept to include all aspects of behavior. Mumford, a sociologist-historian, accepts the ecological approach because it examines the pattern of human institutions in the "whole" in which it takes place. Wheeler insists upon the same general interpretation when he points out that man's behavior is a function of the total field of energy in which he is found. He has, however, analyzed in greater detail the influence of climatic changes.

A survey of the fields which contribute to this general method of approach cannot be undertaken at this time. Many specialized investigations have contributed valuable supplementary evidence. Physiologists have outlined in some detail the methods through which the body adjusts to different conditions of temperature, humidity and atmospheric pressure. The general level of metabolism under different climatic conditions, the functioning of the endocrine system, differences in circulation and composition of the blood as well as many other responses have all been investigated and reported. Typical of such studies are those of Barbour (3), Sundstroem (62), and Bazett (5).

Numerous historians have long found it necessary to consider environmental factors such as climatic changes, natural resources and location in the study of the development of nations. Griffith Taylor (64) (65), Ratzel (60), Draper (19) and others have all pointed out the importance of many such factors.

Many physicians from the time of Hippocrates to the present have been concerned with the influence of different climatic conditions upon the human organism. Thomas, in his survey of environmental theories, mentions many such men. At the present time we find people such as Mills (46) (47), and Petersen (56) concerned with the influence of excessively stimulating climatic conditions upon susceptibility to different diseases, and upon the general levels of metabolism. Petersen points out a possible relation between many physiological changes and even the onset of mental illness to changes in temperature, humidity, and atmospheric pressure.

In addition to the field of human ecology, there are many studies of plant and animal ecology which furnish valuable supporting evidence. Typical are those of Elton (20), Pearse (55) and Clements (15). It should be remembered, however, that these sciences have developed specialized concepts which may not be applicable to human behavior, or must be radically reinterpreted if they are applied. Alihan (1) points out some of the confusions that may arise if this precaution is not observed in his survey of such ecological studies in his Social Ecology.

From the fields of anthropology and geography have come many studies of environmental and geographical influences upon human behavior. Some investigators stress the more indirect influences of natural resources, location and accessibility, while others stress the more direct psychological influences from the natural surroundings.

One of the most recent and comprehensive attempts made by geographers to survey the influence of climatic factors on man is found in the works of Ellsworth Huntington (33) (34) (35). Not only has he been interested in the general relations between climate and civilization, but he also emphasizes the physiological adjustments of the human organism to changing temperatures. Mental and physical efficiency is greatest at certain optimum temperatures, and he finds a definite relation between the rate and quality of reproduction and seasonal climatic fluctuations.

The Specific Problem

As we have seen, there are many studies pointing to the fact that temperature changes are an important field of influence which must be considered in the study of behavior.

As Wheeler suggests, the relation between general behavior patterns and climatic changes may be much more intimate and binding than has previously been suspected. The present study although confined to rats, was motivated by an interest in the larger problem, that of the relation of temperature to behavior in general. An intensive study of this, it is hoped, will throw additional light on the effects of temperature on human behavior. Precisely, then, this is an attempt to find just what changes in behavior take place when the white rat is subjected to controlled differences in temperature. It is believed that under the more rigid controls possible in laboratory techniques more detailed knowledge of the extent and direction of the possible behavior differences can be gained.

There have been relatively few studies which have investigated this relationship. Most of these have been limited to cold-blooded organisms and thus bear only remotely on the present problem. Crozier (16) and Hoagland (30) report some studies along this line. Using ants, Hoagland found that the speed of learning a maze was increased if the temperature was increased, but that continued exposure to higher temperatures brought about a disintegration of the learned behavior.

Two studies by Wever (72) and Hack (23) should also be mentioned. Wever found that water temperature is related to the speed of swimming in the white rat. He reported that the rate of swimming was greatest for low temperatures, and smallest when the water was near body temperature. Higher temperatures were stimulating in that considerable activity was aroused, but it was of a disorganized character. In a similar experiment using a simple water maze, Hack concluded that the learning displayed was in part a function of water temperature. The same general pattern of activity described by Wever was again observed.

French (21) has investigated the effect of temperature on the retention of a maze habit in fish. He tested fish in a simple water maze kept at a temperature of 22° C. Between learning and retention tests the next day, groups equal in learning ability were kept in water maintained at 28°, 16°, or 4° C. He found that the errors made in the retention tests decreased as the temperature of the water in which the fish were kept was lowered. He also noted that fish kept at different temperatures (4°, 16°, 28° C) before original learning mastered the maze at different rates. The cold group was the poorest, in terms of errors, with the warm group next. The medium group made the fewest errors.

Hunter (32) has reported the effect of temperature on the retention of a darkness-avoiding response in cockroaches. Intense cold was found to be unfavorable to relearning, but this was believed due to injury to the animals.

Hellmer's study (24) of the effect of temperature on the behavior of the white rat has the most direct bearing upon the present experiment. Indeed, the present study is the second of a series originally designed to investigate the influence of temperature upon the behavior of the white rat.

Differences in the rate of growth, body structure, and learning ability of rats subjected to different temperatures were all investigated by Hellmer. Three colonies of white rats were raised under the temperature conditions of 55°, 75° and 90° F respectively. The study was carried through two generations. Weight records were kept during the course of the experiment and certain body measurements made when the rats were killed at 21 weeks of age. He found that in the cold room the rats grew most rapidly, matured earlier and gave birth to litters of larger, healthier young. In the hot room growth and maturity were delayed, conceptions were later and fewer, and the litters were smaller in size. The young were weak and many died a few days after birth.

Differences in body size and tail lengths were also found. In the cold room the rats were usually short and stocky, and possessed relatively shorter tails. Rats in the hot room developed longer, more slender bodies and longer tails. These differences were found to increase in the second generation. The difference in rate of growth for the males in each room for the two generations are shown in Figures 1 and 2, reproduced from the data Hellmer reported. (pages 59- and 64) Tables I and II also show the body measurements for the two generations. (pages 68 and 71).

Hellmer's chief interest, however, was in the behavior differences as tested by the ability to learn a simple maze. The rats living under each temperature condition learned the maze, and were tested for retention about thirty days later. The conditions were arranged so that part of the rats living in any one room were required to learn the maze under the other two temperature conditions. For example, some of the rats living in the cold room learned the maze there. Other rats living in the cold room were run in the maze in the 75°, or control room, while still others living in the cold room ran the maze in the 90° room. The same procedure was followed in the other two rooms, so that in all there were nine experimental groups. Table III summarizes some of the data Hellmer reported for both generations, (pages 81 and 95), and gives the trials, errors, and time required to learn the maze. As can be seen, according to the three criteria of learning, the rats from the cold room are from two to three times more efficient in maze performance.

Figure 1

Growth Curves for First Generation Males (From Hellmer)

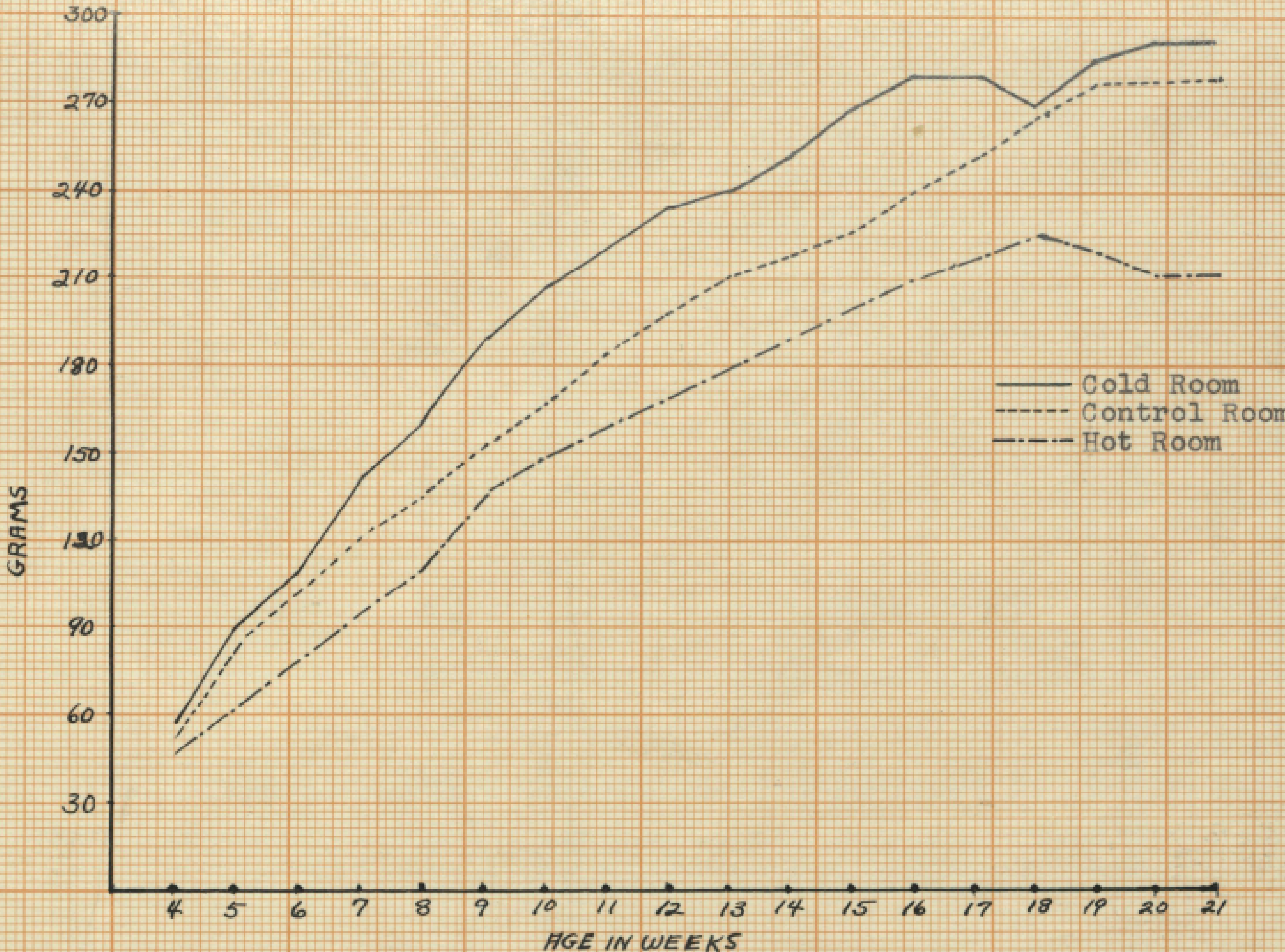


Figure 2

Growth Curves for Second Generation Males (From Hellmer)

TABLE I

MEAN VALUES FOR THE MEASUREMENTS OF THE FIRST GENERATION MALES AND FEMALES AT 21 WEEKS OF AGE (HELIMER)

Group	Mean Body L.	Mean Weight	Mean Tail L.	Mean Body Wt. / Body L.	Mean Body L. / Tail L.
Males					
C	20.9	273	16.7	13.1	1.25
X	20.5	279	18.4	13.6	1.12
H	19.9	246	17.7	12.4	1.12
Females					
C	18.2	187	15.8	10.3	1.15
X	18.3	182	16.7	10.0	1.10
H	17.5	166	16.2	9.5	1.08

TABLE II

MEAN VALUES FOR THE MEASUREMENTS OF THE SECOND GENERATION MALES AND FEMALES AT 21 WEEKS OF AGE (HELIMER)

Group	Mean Body L.	Mean Weight	Mean Tail L.	Mean Body Wt. / Body L.	Mean Body L. / Tail L.
Males					
C	21.1	284	16.2	13.2	1.30
X	21.2	271	17.9	12.8	1.18
H	19.6	200	18.0	10.2	1.09
Females					
C	19.1	208	16.1	10.9	1.19
X	18.8	190	16.5	10.1	1.14
H	18.2	140	16.1	7.7	1.13

TABLE III

MEASURES OF ORIGINAL LEARNING. MEAN SCORES IN TERMS OF TRIALS, ERRORS, AND TIME OF THE NINE EXPERIMENTAL GROUPS FIRST AND SECOND GENERATIONS (HELLMER)

	First Generation				Second Generation			
Group	No.	Trials	Errors	Time	No.	Trials	Errors	Time
Cc	16	13.6	113.4	4857	14	14.7	101.6	4718
Cx	16	22.4	132.9	4512	14	18.3	127.1	5823
Ch	17	27.1	154.5	6121	15	34.3	175.0	10049
Xx	15	21.7	123.9	4005	15	24.9	123.5	3425
Xc	15	27.4	175.9	6691	15	30.7	187.6	7629
Xh	15	28.9	146.2	4881	16	31.6	157.3	5970
Hh	12	53.9	258.8	10579	12	42.8	251.1	8936
Hx	12	47.8	272.4	9735	12	49.0	235.0	8322
Hc	11	60.9	358.2	14109	12	51.3	356.3	16724

The capital letters (C - cold; H - hot; X - control) represent the room in which the group was raised; the small letter the room in which it ran the maze.

Also, the temperature in which the rats learned the maze as well as the temperature of the room in which they were raised was an important factor in maze performance. Hellmer found little significant difference in retention in terms of percentage saving regardless of the temperature. He also points out that, within the limits of the experiment, adaptions to the climatic conditions appear to be continuous and accumulative in the maze performance as well as in the growth differences.

The present study was an attempt to carry the analysis of the differences in behavior of white rats living under different temperature conditions one step further. Here the main purpose was to find out whether the superiority of the cold rats held up when the temperature of their environment was raised, and whether the inferiority of the hot rats continued when the temperature of their environment was lowered. In this method of approach we were interested in finding how rapidly and completely the adaptation, if any, to the new conditions took place. Some attempts to outline more clearly the importance of certain organic changes which might result from differences in motivation were also made.

CHAPTER II

EXPERIMENTAL CONDITIONS

In order to check some of the results reported by Hellmer, the experimental conditions were arranged to duplicate those employed in his study. The same three rooms were used. These rooms were about the same size, with the interior covered with one-inch Insulite. One room was equipped as the cold room, with a Frigidaire refrigerator unit maintaining a temperature of 55-58° F. A fan in the refrigerator unit supplied circulation of air in the room. A temperature of 88-90° was maintained in the second, or hot room, by a small electric heater equipped with thermostatic control. A fan blowing a stream of air over a shallow pan of warm water kept the relative humidity in this room approximately equal to that in the cold room. The third room was kept at room temperature, which varied with the temperature of the building, and a fan in this room also provided circulation. During the first four months of the experiment, the mean temperature was about 75°, while in the last three months the usual temperature range was from 75-78° F.

Thirty albino rats were kept in yet another room of average temperature. While hereditary information concerning the rats was not available, they were healthy animals and there is no reason to doubt that they differed in any important aspects from those used by Hellmer. The rats used in this study were bred and the litters thus secured were used as the experimental animals. Each litter, when four weeks old, was weaned and so divided that members of each litter were placed in each of the three rooms, as nearly in equal numbers as possible. This was done to insure similar hereditary background in the three rooms. For example, in the first litter of six, two of the rats were placed in the cold room, two were placed in the control room, and the remaining pair put in the hot room. At the time each litter was separated, the rats were weighed, and numbered with an ear mark. Rats in each room were numbered consecutively. Division of the litters was made to equate the number of males and females and also the average weight of the rats placed in each room. About sixty rats were placed in each room. The rooms were equipped with steel cage stands with removable cages of hardware cloth. Tops and bottoms of the cages were removable for ease in cleaning cages. Wood shavings was provided for cage bedding in all rooms, and excelsior for nests was placed in the cold room cages. Equal numbers of rats were kept in each cage in all three rooms.

The same diet was provided for all the rats. <u>Purina Fox Chow</u> pellets were kept in the cages at all times, and lettuce was supplied once a week. Drop-tube bottles furnished water, and the rooms were illuminated by 15 watt flourescent lamps. The same routine of light and darkness was observed for the rooms, with from twelve to sixteen hours of light each twenty-four hours.

Weekly weight records were kept for all the rats in each room. These records were started when each rat was weighed at time of separation of the litters at four weeks of age, and continued until the end of the experiment. Daily weight records were kept for all rats while running the mazes. Each rat was weighed on the day prior to maze running, and every day thereafter until the maze had been mastered. Time of weighing was at the time of isolation for maze running or just before performance in the maze.

In order to measure the performance of the same rat in two situations, original and changed temperatures, a technique similar to the transfer experiments in learning was utilized. The sequence of such studies is roughly Test I, intervening period, Test II. Applied to the present study, Test I was conducted in a room of one temperature. Test II in a room of another temperature. Consistent changes in performance of groups moved to different rooms, with temperature as the most important variable factor, would indicate a relation between performance and changes in temperature.

The test selected was learning a relatively simple maze. Approximately forty-five rats in each room were tested in the maze (original learning). After learning, the group of forty-five was divided into three sub-groups of fifteen. Division was made to equate sex and mean trials required for mastery of the maze. Each sub-group of fifteen was then placed in one of the three temperature conditions. For example, in the cold room, one sub-group was left in the cold room, the second sub-group was moved to the control room, and the third sub-group was placed in the hot room. After thirty days in the new rooms, the rats were tested for retention. The retention (relearning) constitutes Test II.

The same procedure was carried out with the forty-five rats in the control room. As soon as the original maze was learned, division was made to equate the sub-groups and these were distributed to each of the three temperature conditions. A similar technique was used with the rats placed in the hot room. Where the sub-groups were changed from one extreme temperature condition to the other, there was introduced a seven-day adjustment period in the control room, in order to avoid a sudden change in temperature that might prove to be too severe. In this fashion the temperature was varied for the rats by changing rooms rather than changing temperatures in the same room.

It was shown in Hellmer's work that the precentage saving on relearning for groups of rats learning in a given room and tested for retention in the same room was approximately equal. That is, rats in the cold room learning and relearning the maze there show about the same percentage saving as rats learning and relearning in the control room. The same is true for those remaining in the hot room for both tests. In the present method, if we find a difference in percentage saving which varies as the temperature changes, we have additional reason to believe that the performance and temperature are related.

Four-alley mazes of standard design were used in the learning which constituted Test I. Mazes of this type, the same as employed by Hellmer, were used by Lashley in his brain extirpation experiments and were found to be reliable. The floor plan of this maze is shown in Figure 3.

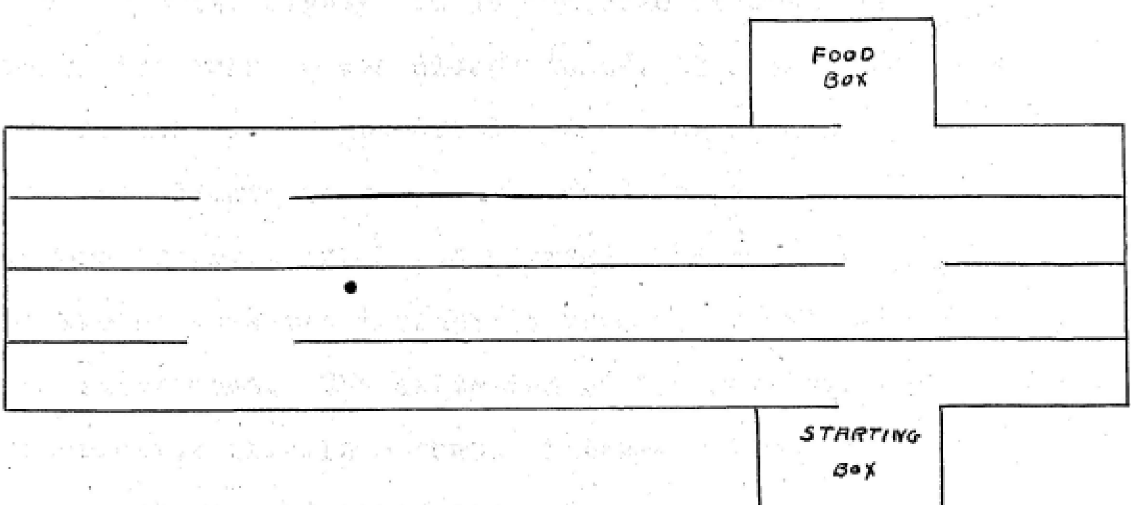


Figure 3. Floor Plan of The Maze

The mazes were placed in each room for the testing periods and removed at completion of the running. The starting box and food box doors were controlled from outside the room by means of strings. A small window in the door of each room enabled the experimenter to record from the outside the errors and time per trial of the rat in the maze. In this manner, disturbing factors during running were kept at a minimum. Uniform lighting conditions were met by placing a 40 watt light two feet above the center of each maze.

Each rat was given one trial the first day of maze running, three trials per day for the next three days, and five trials a day thereafter. If the rat had not learned the maze after thirty-seven trials, it was given ten trials per day until eighty trials had been reached, and at this point the running was discontinued. Twenty minutes was set as the time limit per trial. After an incomplete run the rat was allowed to eat in the food box for thirty seconds before the next trial was started. If the rat still refused to run after seven incomplete trials, it was removed from the experiment. The criterion of learning was set at three consecutive errorless runs. Entrance into a blind alley beyond the shoulders of the rat and back tracking any unit of the maze were counted as errors. All rats were deprived of food for twenty-four hours before running. <u>Gains Dog Meal</u> mixed with enough milk to form a paste was used as the incentive. After completing each trial, the rats were allowed to eat in the food box for about twenty seconds before starting on the next trial. After completion of the day's runs, the rats were allowed to feed for twenty minutes on the same food as was used in the maze. No more food was then given until completion of the next day's trials.

Retention tests were begun approximately thirty days after original learning. Three trials were given the first day, five trials the second day, and ten trials a day thereafter until the maze was relearned. The criterion of learning was three consecutive errorless runs. A twenty minute time limit for each trial was again used, and the rat was removed from the experiment after five incomplete trials. The same experimental conditions were employed as in the original learning. Daily weight records were also kept, starting at the time of food deprivation twenty-four hours before the first trial.

All maze running was carried out in the afternoon and early evening. Several assistants were employed in the experiment, all experienced in this type of work, having aided in the study carried out the year before by Hellmer. They were again carefully instructed as to methods of handling the rats and recording errors and time. In addition, each worked with different groups of rats during the course of maze running, so that no one group would be handled differently over the entire learning process. At all times they were under the immediate supervision of the experimenter and in all did not work with more than one-half of the rats during the course of the experiment.

In an attempt to throw light on the problem of "drive" or motivation raised by Hellmer's experiment, each rat was subsequently tested in an obstruction box. The apparatus was similar to that used by Warden (70) in the Columbia tests. Figure 4 gives the floor plan of the box.

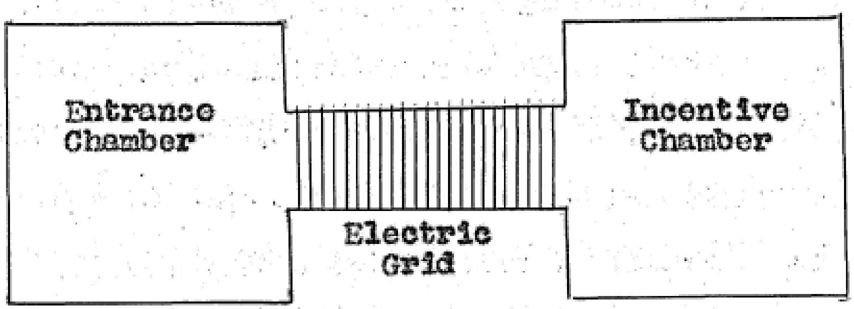


Figure 4

Floor Plan of the Obstruction Box

The starting and incentive chambers were ten inches square, connected by a passageway four inches wide. The floor of this passageway was a removable sheet of bakelite wound with number 26 uninsulated copper wire. The wires were wrapped so that contact with any two adjacent ones completed the circuit and gave the rat a slight shock.

Current was furnished by a small induction coil placed outside the experimental room. The voltage was checked after each test in order to keep it at a constant value. After preliminary trials, the current was set at a value just strong enough to furnish a barrier which about fifty percent of the rats in the control room would cross with little, if any, hesitation. This intensity of current was kept constant for all tests in the three rooms, and the grid was kept clean and dry at all times to avoid short circuiting. Two 40 watt bulbs directly above the inner partitions of the starting and incentive chambers furnished the light.

Two days of exploration were first allowed each rat. Each animal was deprived of food for thirty-six hours before exploration. On the first day the rat was given ten minutes to investigate the box, followed by a fifteen minute feeding period in the incentive chamber. The same food was used as in the maze situation. The second day each rat was given five preliminary test crossings, with a sixty second eating period between crossings. After the five trials each rat was again allowed to feed ten minutes. On the third day the rat was permitted three more practice crossings, with only a nibble of food after each crossing. The current was then connected to the grid, and the test period began. After a crossing, the rat was allowed only a nibble of food. It was then picked up, returned to the entrance chamber and placed in different positions relative to the grid according to a systematic plan.

The preliminary tests on the grid were carried out necessarily in the presence of the experimenter. The rats were handled as gently as possible to avoid introducing disturbing emotional factors, and the lighting was arranged to keep the experimenter relatively obscure in the shadows.

Records of approaches, contacts and crossings of the grid for a twenty minute period were kept. To furnish a more complete picture, this period was divided into four, five minute intervals. Definite orientations toward the food, with the nose even with the connecting passage, were counted as approaches. Contacts were counted when the rat touched the grid with foot or nose and received a shock. Going across the grid and receiving the shock for a nibble of food, of course, constituted a crossing.

As in the maze learning, daily weight records for each rat were kept. These records were started at the time of food deprivation and taken before each trial during the next two days. All grid tests were carried out in the evening between 8 and 12 p. m. The writer was responsible for all these tests.

Since this part of the study was considered of secondary interest in relation to the temperature changes and changes in behavior, none of the elaborate precautions to insure exactly the same shock intensity to each rat were utilized. It is quite possible that the rats did receive slightly different shocks. However, a relatively large number, about fifty in each room, were tested. Subdivision of the groups on the basis of room of origin show little apparent differences in the shock intensity administered.

After the grid experiment was over the rats were killed and body measurements were made. Total length, from the tip of the tail to tip of the nose, as well as tail length, was recorded. The tail length was measured from anus to tip of the tail. Body length was obtained by subtracting tail length from total length. These measurements for groups remaining in the original rooms were used to calculate two ratios; body weight to body length, and body length to tail length. The former ratio gives a picture of the body pattern in terms of grams per centimeter of body length, while the second ratio shows the relative tail lengths more accurately than the absolute measurements.

Table IV summarizes the mean time during which the rats lived in the room to which they had been transferred after original learning, and the average ages for the nine groups at the time of each of the three tests, original learning, relearning, and the grid experiment.

TABLE IV

MEAN TIME IN THE NEW ROOMS BEFORE RELEARNING AND MEAN AGES AT TIME OF RELEARNING AND GRID TESTS

	Age first trials	Time in new room before relearning	Age relearning	Age grid trials
Cold Room Rats				
a. left in C	89.3	35.9	134.9	150.6
b. moved to X	89.4	39.9	135.2	153.6
c. moved to H	88.7	35.6	133.6	150.9
Control Room Rats				
a. moved to C	91.8	38.1	136.6	151.3
b. left in X	89.4	40.3	136.2	155.3
c. moved to H	89.3	40.8	136.2	153.3
Hot Room Rats				
a. moved to C	91.3	31.6	137.4	155.9
b. moved to X	87.9	39.7	136.1	151.5
c. left in H	88.1	39.0	135.4	159.4

CHAPTER III

RESULTS

Differences In Rate Of Growth and Body Structure

In presenting the results of a study involving the behavior of a large number of individuals, certain statistical data are necessary. In the present study no doubt a number of methods of presenting the results statistically could be utilized. It has been the intent of the writer to use only the simpler measures and methods, as the primary purpose is to point out differences found, and not to make the data obtained an exercise in statistical manipulation.

The usual measures of variability and reliability of means were employed. In comparing the performance of different groups some idea of the reliability of the differences between means is needed. Although the critical ratio has certain disadvantages, especially when the samples used are small, it has been calculated as a measure of the reliability of the differences. This was done, primarily, in order to compare results of the present study with those reported by Hellmer.

It is believed that the statistical tools employed are sufficient for the results obtained. We are interested not only in establishing the fact of differences in performance, but to begin to point out possible ways in which these differences may be related. In doing this our rationalizations may be based upon tendencies which, statistically insignificant, are from other lines of evidence, obviously important. Consistent, though small, differences, biologically related factors, and evidence from similar studies are all important for our purpose and may be as valuable as some of the relatively artificial statistical values.

The general picture obtained from the growth curves corresponds to that found by Hellmer. Those rats living in the cold room grow more rapidly and exhibit a larger averaged weight per week than rats in the other two rooms. Figure 5 shows the growth curves for the rats in each room from the fourth to the tenth weeks. Here it will be noticed that the rats in the hot room show a more rapid rate of growth than the control group for the first few weeks, but end up below this group at the tenth week. When the litters were divided at four weeks of age, the average weights for the cold, control and hot rooms were 45.9, 44.1, and 44.7 grams, respectively. At the end of the tenth week the weights were 157.9, 145.7, and 141.5 grams, respectively.

Further information concerning the rate of growth can be gained by examination of the growth curves for each subgroup in the different rooms. As said before, each of the original groups was divided into three sub-groups, one being placed in each temperature condition after learning the maze

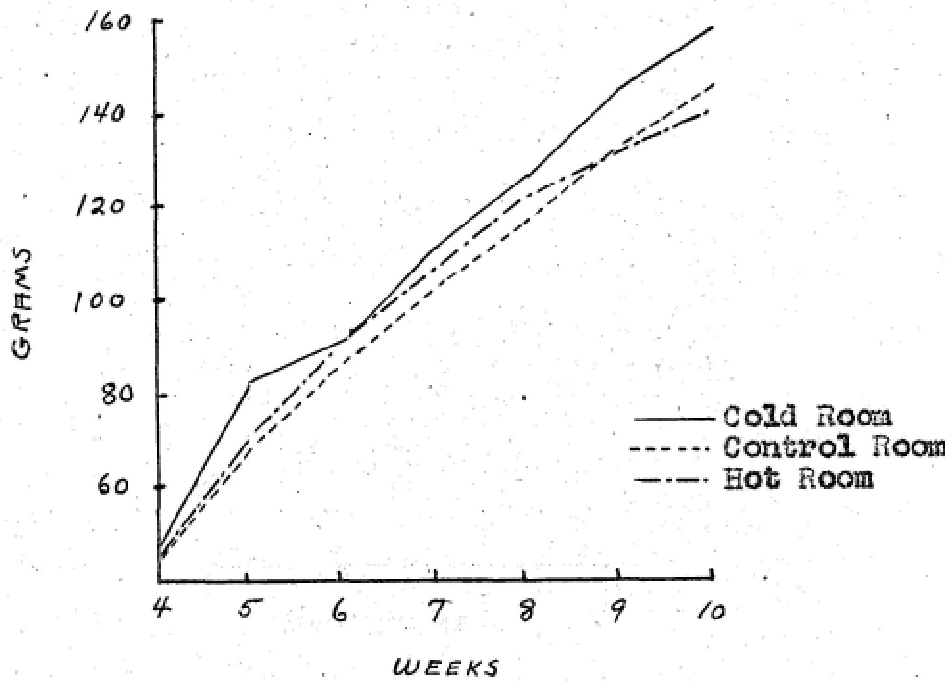


Figure 5

Growth Curves for all Rats in Each Room--Fourth to Tenth Weeks

for the first time. Thus some of the growth curves are for groups which lived in one room from four to ten weeks, and then spent the next eight weeks under some other temperature. The results of such changes are shown in the following growth curves, Figures 6, 7, and 8.

A study of the curves indicates that switching a group from one extreme temperature condition to the other acts to

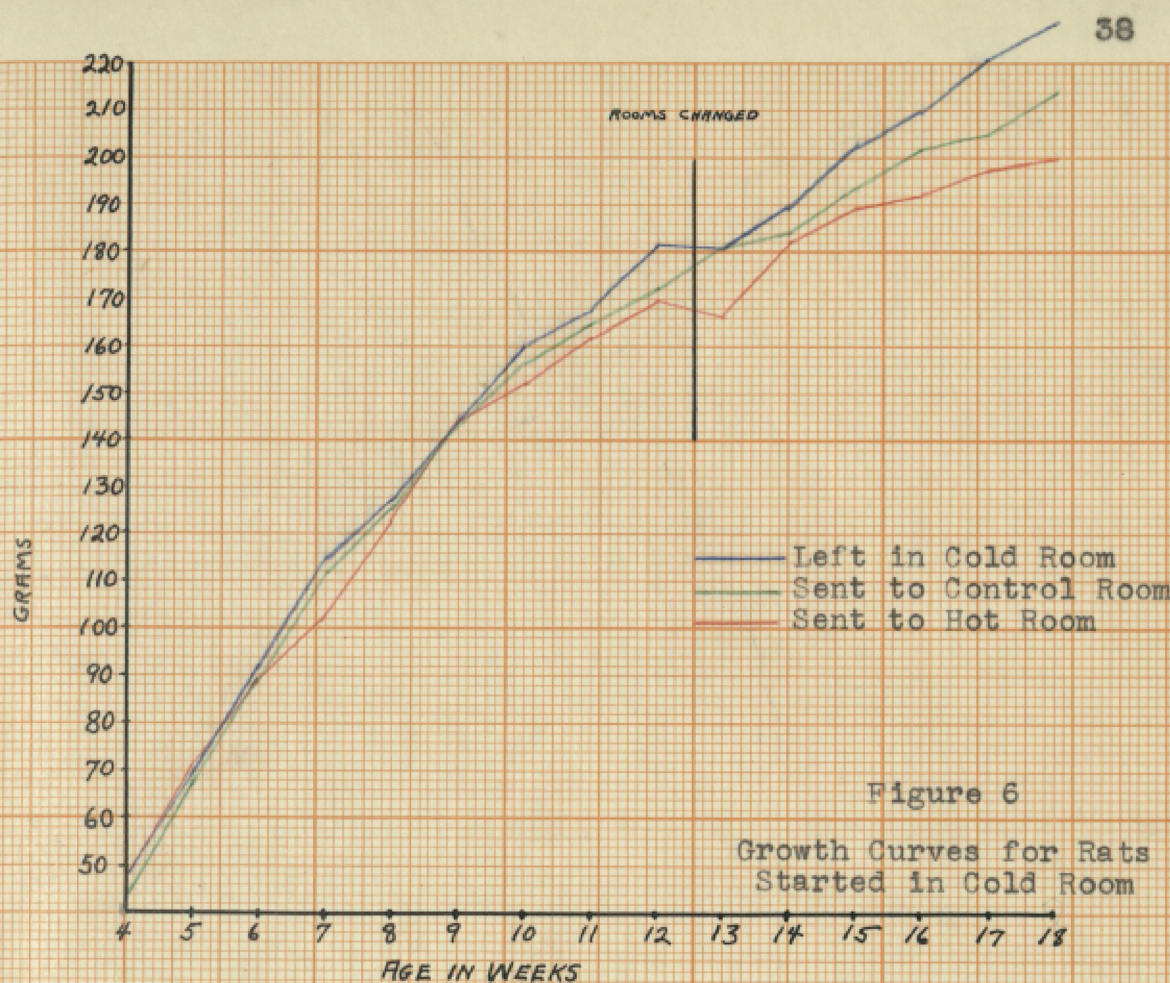


Figure 6

Growth Curves for Rats Started in Cold Room

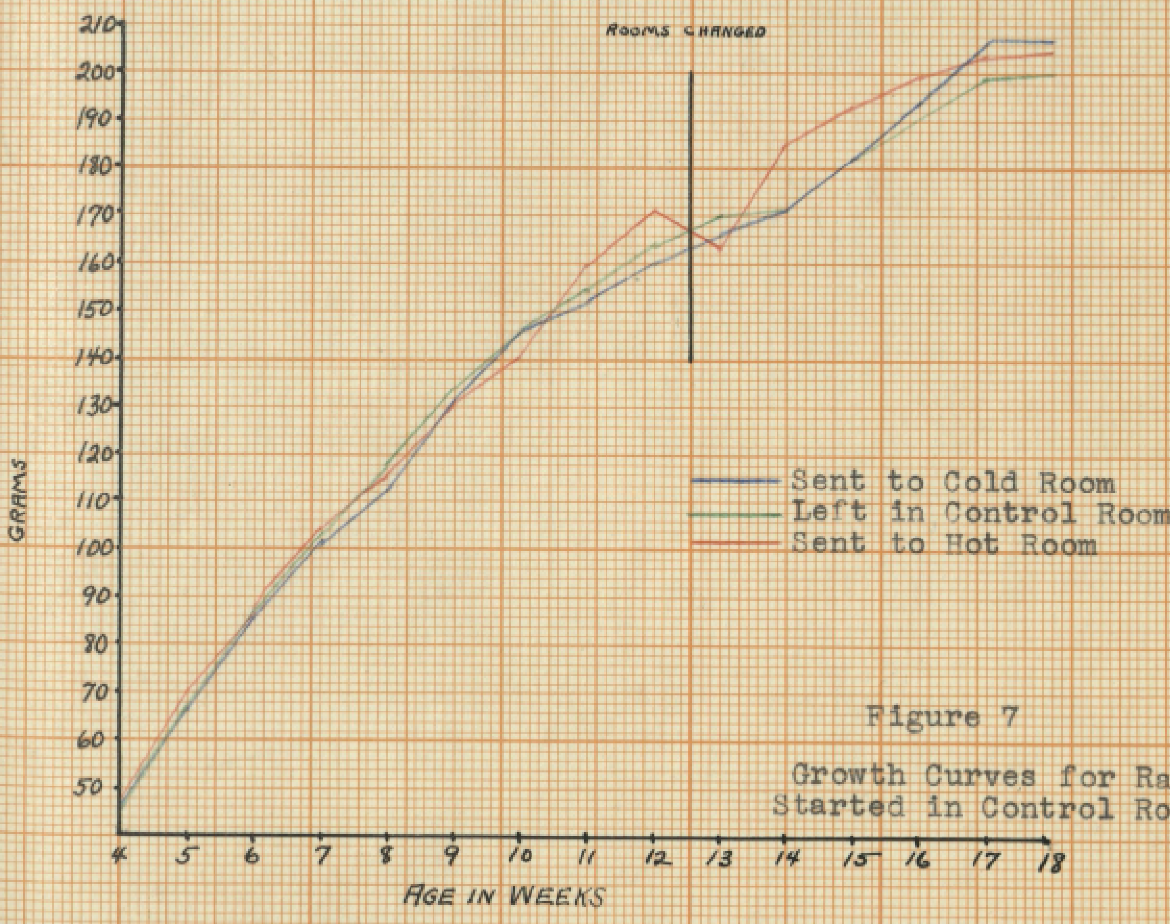


Figure 7

Growth Curves for Rats Started in Control Room

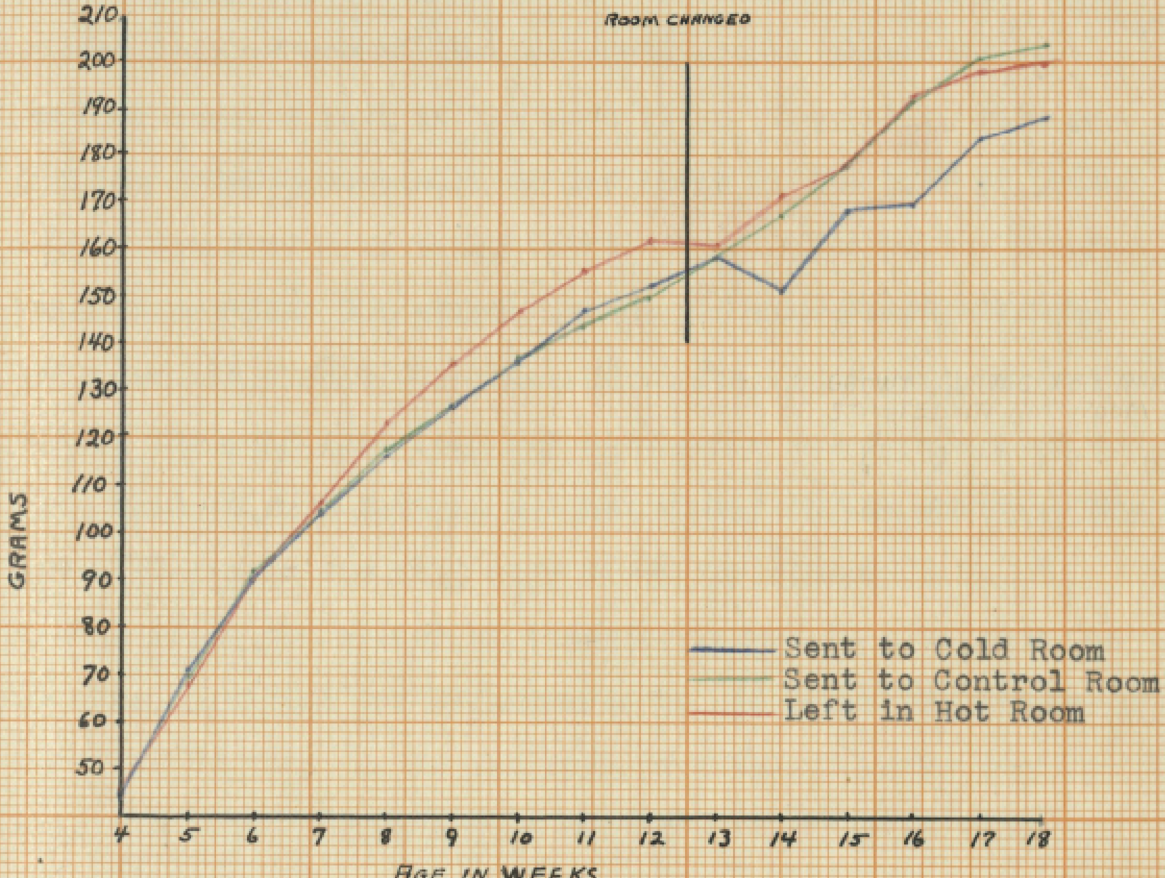


Figure 8

Growth Curves for Rats Started in Hot Room reduce the rate of growth below that of groups left in the original room or sent to the control room. For example, the cold room group, after placement in the hot room shows a slower rate of growth than do equal groups placed in the control room or left in the cold room. A trend in this direction would be expected on the basis of the rate of growth during the fourth to tenth weeks of the experiment. However, when we consider the growth curves for rats started in the hot room, it should be noticed that placing a group from the hot in the cold room does not accelerate its development beyond that of rats left in the hot room. On the contrary the group placed in the cold room shows the slowest rate of growth after the change of rooms is made. In this case, it is true, division was unfortunate in the sense that the rats selected to stay in the hot room seem to grow more rapidly than the other groups before the time of changing rooms. However, this early advantage is overtaken by the hot room rats placed in the control room, while the group placed in the cold room show the slowest rate of growth.

In the case of the rats starting in the control room, changes to either the cold or hot room serve to stimulate the growth rate. The differences are slight, however, and may not be significant.

A number of the rats were kept in the original rooms throughout the entire course of the experiment and certain body measurements taken when the rats were killed. Tail length and body length were recorded. In the data reported here, no attempt has been made to separate the groups as to sex. Each group, however, contained approximately the same number of males and females. The age at the time the measurements were made was not exactly the same, but the same number of rats of each age were taken from each room. The mean values for tail and body lengths, as well as some indication of the reliability of these differences are given in Tables V and VI.

TABLE V

MEAN TAIL AND BODY LENGTHS FOR RATS SPENDING ENTIRE PERIOD IN SAME ROOM

	Tail Length				Body Length				
Room	No	Mean	σ	σ ave.	No	Mean	σ	σ ave.	Body L. / Tail L.
Cold	30	16.5	.90	.16	38	20.0	1.38	.22	1.21
Control	38	17.4	.99	.16	40	19.7	1.4	.22	1.13
Hot	36	18.0	.86	.14	39	19.3	1.2	.19	1.07

TABLE VI

RELIABILITY OF DIFFERENCES BETWEEN MEAN TAIL LENGTHS AND BODY LENGTHS FOR RATS SPENDING ENTIRE PERIOD IN SAME ROOM

	Tail Lengths				Body Lengths			
Group	Mean	Diff.	σ Diff.	C.R.	Mean	Diff.	σ Diff.	C.R.
C	16.5				20.0			
		.9	.22	4.1		.3	.31	.97
X	17.4				19.7			
C	16.5				20.0			
		1.5	.22	6.8		.7	.3	2.33
H	18.0				19.3			
X	17.4				19.7			
		.6	.20	3.0		.4	.3	1.33
H	18.0				19.3			

The tail lengths tend to increase as the temperature conditions are increased. From the tables, it would also seem that the body lengths vary in the same manner. However, as the rats living in the cold room tend to grow to a larger overall size, the ratio of body length to tail length gives a better picture of the relative body and tail lengths in each room. The values for this ratio indicate that the rats in the cold room not only have shorter tails in terms of absolute measurements, but also relatively shorter tails when compared to the body length. The critical ratios for the differences between the tail lengths are all 3.0 or above. For the body lengths the ratios are much smaller, probably not large enough to indicate a reliable difference.

A comparison of these values with those reported by Hellmer is of interest here. Combining his measurements for males and females of the first generation (See Tables I and II), we have the following tail lenghts; 16.3 cm. for the cold room; 17.6 cm. for the control; and 17.0 cm. for the hot room. With the exception of the hot room group, his results correspond closely with those reported here. The ratios of body length to tail length can also be compared. Hellmer reports 1.20 for both males and females in the cold room, 1.11 for the control room, and 1.10 for the hot room group. From Table V the present values are 1.21, 1.13, and 1.07.

As there is little difference in the body lengths of the animals in each room, the ratio of body weight to body length gives a better picture of the long narrow versus the short chunky body pattern. The values thus found give the grams of body weight per linear centimeter of body length. These ratios decrease from a maximum of 11.7 gr. per cm. for the cold room group to 10.5 for the control room to 10.3 for the hot room group. Hellmer reported 11.7, 11.8, and 10.9 for the corresponding ratios. Although there is only a slight difference in the present values between hot and control room groups, and Hellmer's control group is out of place, the trend is the same in both experiments. The cold room rats tend to have heavier, stockier bodies than their litter mates living under the higher temperatures.

As Mills (47) has suggested, this would seem to demonstrate a change in bodily structure in the process of adaptation to the conditions under which the animal is forced to live. Exposure of a greater surface area, especially tail area in the case of the rat, no doubt facilitates loss of body heat. In the rooms of higher temperatures, greater amounts of body heat must be lost, and this may be one of the factors responsible for the differences found in the three rooms.

Maze Performance

In the main part of the experiment, standards for maze performance in each room were first established. Equal groups, in terms of trials required for mastery of the maze, were then placed in each of the three temperature conditions and the relearning scores determined 40 days later. Thus the group in each room learning and relearning under the same conditions acts as a control or furnishes standards of performance for the groups relearning under different conditions. Using such a procedure, it is possible that in the period between learning and relearning disturbing factors other than the temperature change may enter. Moving a rat from one room to another, to new surroundings and cage mates, might possibly act as a disturbing factor to change the performance. Of the three sub-groups in each room, two were disturbed, one left undisturbed. If the moving itself is a complicating factor, it is equally distributed among the three rooms. Also, if moving a rat acts to disturb its performance, we would expect to find lower relearning scores in those groups placed in other than the original room. However, the relearning scores did not vary in such a fashion, but in some instances were just opposite this trend. In each case it will be seen that the temperature was the important variable in producing different scores in different rooms.

Table VII gives the mean trials, errors, and time required for mastery of the maze the first time. The medians and ranges for the performance of the groups are given in Table VIII.

In terms of trials, errors, and time, the cold room rats learn the maze most rapidly. The control room stands next with the rats in the hot room showing the poorest performance. As the temperature of the room in which original learning takes place increases, the performance decreases. Variability of performance changes in the reverse manner; as the temperature increases, variability increases. Values for

TABLE VII

MEASURES OF ORIGINAL LEARNING. MEAN SCORES IN TERMS OF TRIALS, ERRORS, AND TIME

		Trials			Errors			Time		
Group	No.	Mean	σ	$\sigma/\sqrt{n}$	Mean	σ	$\sigma/\sqrt{n}$	Mean	σ	$\sigma/\sqrt{n}$
Cold	47	19.8	7.36	1.07	141	72.3	10.5	4443	2926.5	426.6
Control	46	25.9	13.30	1.96	143	80.7	11.9	5180	3664.8	540.5
Hot	47	36.6	19.10	2.78	245	131.8	19.2	8270	5487.9	799.9

TABLE VIII

MEANS, MEDIANS, AND RANGES FOR THE THREE ORIGINAL GROUPS IN MAZE LEARNING

		Trials			Errors			Time		
Group	No.	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range
Cold	47	19.8	18.0	8 to 38	141	128.0	24 to 325	4443	4395	487 to 11490
Control	46	25.9	20.5	11 to 68	143	116.5	25 to 460	5180	4281.5	937 to 19384
Hot	47	36.6	33.0	10 to 80	245	195.0	74 to 555	8270	6899	1825 to 25790

d/σ_d also indicate that these averages are reliable. The medians are in every case somewhat lower than the means and on two occasions there is a reversal of the trend found in the means. The median errors and time for the control room rats is a little below corresponding values for the cold room. However, differences between median errors and time for the cold and hot rooms are quite large. It will also be noticed that the range of performance increases as one goes from the cold to the hot rooms.

Reliability of the means reported are shown by Table IX. Measured in terms of the critical ratio, the differences found in original learning are significant. The lowest values are for differences between cold and control rooms, especially in terms of time and errors. The greatest values of the critical ratio appear between the cold and hot rooms. As later tables will indicate, this also appears to be the case in measures of relearning.

Hellmer reports greater differences between his hot and cold room groups. He found 13.6 trials as the mean score for the group which corresponded to the present cold room group, 21.7 for the control room, and 53.9 for the hot room. The differences can no doubt be accounted for by slight changes in procedure followed in the present experiment. The hot room rats were stopped after 80 trials, rather than 100 as in Hellmer's method. He divided the original group in

TABLE IX

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN TERMS OF TRIALS, ERRORS, AND TIME FOR THE ORIGINAL GROUPS

Group	Trials				Errors				Time			
	Mean	Diff.	σ Diff.	C.R.	Mean	Diff.	σ Diff.	C.R.	Mean	Diff.	σ Diff.	C.R.
C X	19.8 25.9	6.1	2.23	2.74	141 143	2.0	15.9	.13	4443 5180	737	688.5	1.07
C H	19.8 36.6	16.8	2.98	5.6	141 245	104	21.9	4.75	4443 8270	3827	906.5	4.22
X H	25.9 36.6	10.7	3.4	3.1	143 245	102	22.6	4.5	5180 8270	3090	965.4	3.2

such a way as to leave only 15 rats for learning in the original rooms; in the present study over 45 were tested in each of the three conditions and thus constitute a more adequate sample.

As outlined earlier, each original group was divided into three equal sub-groups as the maze was mastered. This division was made on the basis of trials required for three errorless runs. In some instances, there is a difference of a trial or two between groups which were equated. However, if the groups going to any one room were not consistently favored, such a division can be considered as fulfilling the desired end. Table X shows the distribution of the 9 sub-groups in terms or trials, errors, and time.

On the basis of trials, <u>the hot room is favored twice</u>. That is, of the three original groups, the sub-groups placed in the hot room had the lowest score in terms of trials in two of the three original rooms. The cold room is favored only once on this basis. With errors as the criterion, the hot, control and cold rooms were each favored once. Using time as the standard, the hot room is favored once, <u>the cold room twice</u>. Thus considering all three criteria, the hot room was given an advantage 4 of the 9 possible measures, the control 3 of the 9, and the cold, 2. <u>The division was made in such a manner as presumably to give an advantage to the groups which were later found to be the slowest in rate</u>

TABLE X

DISTRIBUTION OF THE GROUPS ON THE BASIS OF TRIALS, ERRORS, AND TIME

	Mean Trials	Mean Errors	Mean Time
Cold Room Rats			
a. Left in C	20.2	118.0	4215
b. Moved to X	20.0	163.2	4697
c. Moved to H	19.2	140.6	4021
Control Room Rats			
a. Moved to C	26.1	143.6	5225
b. Left in X	26.3	159.3	4715
c. Moved to H	25.7	128.5	5169
Hot Room Rats			
a. Moved to C	35.4	254.5	8473
b. Moved to X	37.3	230.9	8025
c. Left in H	37.5	255.6	8571

and efficiency of learning. Differences in division can not then be the basis for the differences exhibited in relearning.

Mean trials, errors, and time in relearning for the 9 sub-groups are given in Table XI. If one takes the cold room as an example, one finds that the sub-group of 14 rats which were left in that room and tested for relearning approximately 40 days later, took an average of 7.1 trials,

TABLE XI

TRIALS, ERRORS AND TIME FOR THE NINE EXPERIMENTAL GROUPS--RELEARNING

		Trials			Errors			Time		
	N	Mean	σ	$\sigma/\sqrt{N}$	Mean	σ	$\sigma/\sqrt{N}$	Mean	σ	$\sigma/\sqrt{N}$
Cold Room Rats										
a. Left in C	14	7.1	4.15	1.1	17.4	18.37	4.90	559	732.0	195.7
b. Moved to X	17	9.8	4.77	1.1	31.8	25.11	6.09	1090	1052.1	255.4
c. Moved to H	14	13.0	6.48	1.7	50.6	31.80	8.50	1336	1187.3	317.5
Control Room Rats										
a. Moved to C	14	7.9	3.45	.9	31.3	32.08	8.58	702	715.4	191.3
b. Left in X	15	11.3	6.77	1.8	40.0	38.56	9.96	2009	2778.1	717.9
c. Moved to H	15	18.8	9.22	2.4	70.4	46.90	12.1	1909	1576.6	407.4
Hot Room Rats										
a. Moved to C	16	8.2	3.28	.8	28.9	22.72	6.93	1019	1507.1	376.8
b. Moved to X	15	10.5	4.56	1.2	36.5	43.09	11.1	749	689.8	180.6
c. Left in H	14	16.5	9.76	2.6	47.6	20.32	5.43	1715	2203.9	589.3

17.4 errors, and 559 seconds for mastery of the maze the second time. A second sub-group from the same room, learning the maze in an equal number of trials, but relearning in the control room after 40 days, needed 9.8 trials, 31 errors, and 1090 seconds for mastery. A third sub-group, again with an equal score on original learning, but moved to the hot room for relearning, needed on the average 13.0 trials, 50.6 errors, and 1336 seconds to relearn the maze 36 days later.

The same trend can be observed in the control and hot room rats relearning the maze in each of the three temperature conditions. Every time the sub-group is moved to a room of lower temperature, the number of trials needed decreases, and increases as equal groups are placed in rooms of higher temperature. It must be noticed, however, that in the standard of total time required, there are 2 irregularities in this trend. The control rats relearning in the control room require greater time than do the control room rats relearning in the hot room. Also, the hot room rats relearning in the cold room need more time than do the hot room rats relearning in the control room. Time scores, however, are usually considered the least reliable of the three criteria of learning. Also, the differences between the time scores of the sub-groups from any one room, moved to the hot and cold rooms, are quite large.

Variability of performance follows a trend similar to that found in original learning. The size of the standard deviations increase as sub-groups originally from the same room relearn the maze in rooms of higher temperature. This trend can be observed in all three standards employed. The means reported here are also reliable if trials are taken as the standard of performance. The standard errors are all low, with the means ranging from 7 to 10 times the standard error. With errors as the standard, the means are from 3½ (twice in 9 cases) to 8 times as large as the standard errors. The time scores are probably least reliable with means ranging from 3 to 4 times the standard errors.

The medians and ranges for the 9 sub-groups are given in Table XII. Again, as equal groups are placed in rooms of higher temperature, the median score in terms of trials, errors and time tends to increase. The range also increases in this same manner. Examination of the median scores shows only one exception to this tendency. Hot room rats relearning in the control room take 13 seconds less than do a corresponding group in the cold room.

Reliability of the differences between means for the 9 groups used here are given in Table XIII. The critical ratios for the differences between groups relearning in the hot and cold rooms are all large enough to indicate that similar results can be expected in future trials. The values

TABLE XII

MEAN, MEDIAN, AND RANGES FOR THE TRIALS, ERRORS, AND TIME, OF THE NINE EXPERIMENTAL GROUPS

		Trials			Errors			Time		
	N	Mean	Med.	Range	Mean	Med.	Range	Mean	Med.	Range
Cold Room Rats										
a. Left in C	14	7.1	6.0	3 - 19	17.4	11.0	0 - 67	559	215	52 - 2735
b. Moved to X	17	9.8	10.0	4 - 19	31.8	29.0	3 - 79	1090	667	121 - 3418
c. Moved to H	14	13.0	12.5	5 - 29	50.6	43.5	4 - 117	1336	1063	67 - 4014
Control Room Rats										
a. Moved to C	14	7.9	7.0	4 - 12	31.3	18.0	1 - 117	702	346	97 - 2447
b. Left in X	15	11.3	10.0	3 - 27	40.0	28.0	1 - 137	2009	819	68 - 9882
c. Moved to H	15	18.8	17.0	9 - 45	70.4	55.0	17- 171	1909	1167	441 - 3916
Hot Room Rats										
a. Moved to C	16	8.2	7.5	4 - 16	28.9	20.5	8 - 126	1019	516	125 - 5368
b. Moved to X	15	10.5	8.0	4 - 20	36.5	25.0	5 - 166	748	503	163 - 2563
c. Left in H	14	16.5	14.0	5 - 40	47.6	44.5	17- 89	1715	1146	269 - 9309

TABLE XIII

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES BETWEEN MEANS OF TRIALS, TIME AND ERRORS FOR THE NINE EXPERIMENTAL GROUPS*

Group	Trials				Errors				Time			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
Cc	7.1	2.7	1.54	1.75	17.4	14.4	7.82	1.84	559	531	321.7	1.65
Cx	9.8				31.8				1090			
Cc	7.1	5.9	2.02	2.9	17.4	33.2	9.81	3.4	559	777	372.9	2.08
Ch	13.0				50.6				1336			
Cx	9.8	3.2	2.02	1.58	31.8	18.8	10.45	1.8	1090	246	407.5	.6
Ch	13.0				50.6				1336			
Xc	7.9	3.4	1.98	1.7	31.3	8.7	13.15	.66	702	1307	742.9	1.76
Xx	11.3				40.0				2009			
Xc	7.9	10.9	2.55	4.27	31.3	39.1	14.83	2.64	702	1207	450.1	2.68
Xh	18.8				70.4				1909			
Xx	11.3	7.5	2.95	2.54	40.0	30.4	15.7	1.97	2009	100	825.4	.12
Xh	18.8				70.4				1909			
Hc	8.2	2.3	1.43	1.6	28.9	7.6	13.11	.58	1019	271	417.8	.65
Hx	10.5				36.5				748			
Hc	8.2	8.3	2.73	3.04	28.9	18.7	8.8	2.13	1019	696	699.2	.99
Hh	16.5				47.6				1715			
Hx	10.5	6.0	2.86	2.1	36.5	11.1	12.38	.90	748	967	616.2	1.57
Hh	16.5				47.6				1715			

* The letters c, x, h, indicate the room in which sub-groups relearned the maze.

for differences between groups relearning in the hot and control rooms are in general next in size, while the smallest ratios are found for the differences between groups relearning in the cold and control rooms. This same trend can be found in the ratios calculated for the error and time scores, but they are somewhat lower.

Table XIV is presented in order to see if there are significant differences between the groups originally learning the maze in different rooms, but which relearned in the same room. This was done to see if the difference found in original learning persisted when the rats were placed in new conditions. If this does occur, the sub-groups coming from the cold room would be expected to show the best performance of the sub-groups in any room, with the control and hot room rats standing second and third. Examination of the scores of the rats relearning in the cold room indicates that in terms of trials, the group originally learning the maze in the cold room stands first, those from the control room are second, while the hot room rats require the greatest number of trials. For errors, the sequence is CHX[1] and for total time, CXH. However, the differences are slight, and the values for the critical ratios (Table XV) do not in themselves warrant the belief that such differences as those are significant.

1. The symbols C, X, H stand for groups originally learning the maze in the cold, control and hot rooms, respectively.

The sub-groups relearning in the control room have the order CHX for trials, CHX for errors, and HCX for time. Again, Table XV indicates that the critical ratios are not large enough to suggest that these differences are reliable statistically. In the hot room, the order in relearning is CHX for trials, HCX for errors, and XCH for time. Critical ratios for the reliability of these differences are somewhat larger, but still too small to be very significant.

TABLE XIV

RELEARNING SCORES GROUPED BY ROOMS

	Trials	Errors	Time
Rats relearning in cold room			
a. From cold room	7.1	17.4	559
b. From control room	7.9	31.3	702
c. From hot room	8.2	28.9	1019
Rats relearning in control room			
a. From cold room	9.8	32.0	1090
b. From control room	11.3	40.0	2009
c. From hot room	10.5	36.5	749
Rats relarning in hot room			
a. From cold room	13.0	50.6	1336
b. From control room	18.8	70.4	1009
c. From hot room	16.5	47.6	1715

TABLE XV

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES BETWEEN MEANS OF TRIALS, ERRORS AND TIME WHEN GROUPED BY ROOMS FOR RELEARNING

Group	Trials				Errors				Time			
	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.
Cc Xc	7.1 7.9	.8	1.4	.57	17.4 31.3	13.9	9.88	1.40	559 702	143	273.7	.52
Cc Hc	7.1 8.2	1.1	1.37	.80	17.4 28.9	11.5	8.48	1.36	559 1019	460	424.6	1.08
Xc Hc	7.9 8.2	.3	1.23	.24	31.3 28.9	2.4	11.03	.22	702 1019	317	422.6	.75
Cx Xx	9.8 11.3	1.5	2.06	.73	31.8 40.0	8.2	11.67	.70	1090 2009	919	716.9	1.28
Cx Hx	9.8 10.5	.7	1.26	.56	31.8 36.5	4.7	12.68	.37	1090 748	342	308.6	1.11
Xx Hx	11.3 10.5	.8	2.11	.38	40.0 36.5	3.5	14.90	.23	748 2009	1261	740.3	1.70
Ch Xh	13.0 18.8	5.8	2.92	1.98	50.6 70.4	19.8	14.80	1.34	1336 1909	573	516.50	1.11
Ch Hh	13.0 16.5	3.5	3.11	1.13	50.6 47.6	3.0	10.08	.30	1336 1715	379	669.4	.57
Xh Hh	18.8 16.5	2.3	3.52	.65	70.4 47.6	22.8	13.26	1.72	1909 1715	194	716.4	.27

It should be remembered, however, that purely statistical tests have definite limitations. Consistency in trends, even though absolute differences may be small, are certainly important signs of possible relationships. In the relearning in each of the three rooms, it was found that rats learning the maze in the control room and relearning in any of the three rooms show the poorest performance. This is true in 6 of the 9 possible combinations, using trials, errors and time as standards. Even in the original room, control rats relearning there have a poorer score than do rats coming from either the cold or hot rooms. In no case did the sub-groups from the cold room stand last, while those from the hot room were in last place in 3 of the 9 chances.

While the cold room groups do stand first in 6 of the 9 measures, it is the hot room groups which stand second place most frequently, with the control room groups coming last the greatest part of the time. Thus if there is a tendency for the cold room to set up processes which may be carried over into other rooms and for a time influence behavior, corresponding tendencies arising from the hot room are lost rapidly. The relatively poor performance of the control room sub-groups also suggests the possibility that these rats, when moved to other rooms, are at a disadvantage. Confronted for the first time with the problems of adaptation to new conditions at a later period of their life, they may not be able to make such changes as these readily. Perhaps the cold and hot room rats, having once adjusted to unusual conditions, are able to do so again with relatively greater ease. This explanation, however, fails to account for the poor performance of the control rats remaining in the control room, unless the assumption is made that the move from hot to control room acts to stimulate in some way the rats from the hot room.

Tables XVI, XVII, and XVIII give the critical ratios, listed in order of magnitude, for differences between groups measured in terms of trials, errors, and time. Each group is compared with every other group. In all 3 standards, the general trend is for the highest critical ratios to occur between groups relearning in the cold and hot rooms, regardless of origin. The low critical ratios usually are found between groups relearning in the same room, no matter where original learning took place. Nine of the first twelve critical ratios are between groups relearning in the hot and cold rooms. Eight of the last ten are between rats relearning in the same room. When errors or time are considered, the distribution is not quite so striking, but it follows the same order. For errors, seven of the first ten C.R.'s are between rats relearning in the cold and hot rooms, with four of the last ten between groups relearning in the same room. When time is considered, six of the total nine critical ratios for differences between the hot and cold rooms are included in the first twelve ratios. The last ten ratios include more differences between c-x and x-h groups.[1] Three of the last 10 included groups relearning in the same room.

1. The small symbols c, x, h, indicate the room in which sub-groups relearned the maze. When used with C, X, or H, the room of original learning as well as the room in which relearning took place is indicated. Thus Cc is used to identify the group learning and relearning the maze in the cold room.

TABLE XVI

GROUP DIFFERENCES FOR RELEARNING IN TERMS OF TRIALS RANKED ACCORDING TO THE SIZE OF THE CRITICAL RATIO*

Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C.R.
1	Cc Xh	4.47	10	Cc Hx	2.70	19	Cc Cx	1.75	28	Ch Hh	1.13
2	Xc Xh	4.27	11	Xc Ch	2.64	20	Xc Xx	1.70	29	Cc Hc	.8
3	Hc Xh	4.20	12	Hc Ch	2.54	21	Xx Hh	1.66	30	Cx Xx	.73
4	Cx Xh	3.44	13	Xx Xh	2.54	22	Hc Xx	1.60	31	Xx Ch	.70
5	Cc Hh	3.30	14	Cx Hh	2.40	23	Hc Hx	1.60	32	Hh Xh	.65
6	Hx Xh	3.13	15	Hx Hh	2.10	24	Cx Ch	1.58	33	Cc Xc	.57
7	Xc Hh	3.12	16	Cc Xx	2.04	25	Xc Cx	1.33	34	Cx Hx	.56
8	Hc Hh	3.04	17	Ch Xh	1.98	26	Hx Ch	1.20	35	Hx Xx	.38
9	Cc Ch	2.90	18	Xc Hx	1.80	27	Hc Cx	1.17	36	Xc Hc	.24

* In Tables XVI, XVII, XVIII, the group with smallest learning score is placed first in each pair considered.

TABLE XVII

GROUP DIFFERENCES FOR RELEARNING IN TERMS OF ERRORS RANKED ACCORDING TO THE SIZE OF THE CRITICAL RATIO

Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C.R.
1	Cc Hh	4.13	10	Hc Ch	1.99	19	Cc Xc	1.40	28	Xc Xx	.66
2	Cc Xh	4.06	11	Xx Xh	1.97	20	Cc Hc	1.36	29	Hc Hx	.58
3	Cc Ch	3.40	12	Cx Hh	1.94	21	Ch Xh	1.34	30	Cx Hx	.37
4	Hc Xh	2.98	13	Cc Cx	1.84	22	Hx Ch	1.01	31	Xc Hx	.37
5	Cx Xh	2.85	14	Cx Ch	1.80	23	Hc Xx	.95	32	Hc Cx	.31
6	Xc Xh	2.64	15	Hh Xh	1.72	24	Hx Hh	.90	33	Hh Ch	.30
7	Hc Hh	2.13	16	Xc Hh	1.60	25	Xx Ch	.81	34	Hx Xx	.23
8	Hx Xh	2.06	17	Xc Ch	1.59	26	Cx Xx	.70	35	Hc Xc	.22
9	Cc Xx	2.04	18	Cc Hx	1.57	27	Xx Hh	.67	36	Xc Cx	.05

TABLE XVIII

GROUP DIFFERENCES FOR RELEARNING IN TERMS OF TIME RANKED ACCORDING TO THE SIZE OF THE CRITICAL PERIOD

Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C.R.
1	Cc Xh	2.99	10	Hx Xx	1.70	19	Hx Cx	1.11	28	Hc Ch	.64
2	Xc Xh	2.68	11	Cc Cx	1.65	20	Ch Xh	1.11	29	Cx Ch	.60
3	Hx Xh	2.60	12	Xc Hh	1.64	21	Cc Hc	1.08	30	Ch Hh	.57
4	Cc Ch	2.08	13	Hx Ch	1.61	22	Cx Hh	1.01	31	Xc Xc	.52
5	Cc Xx	1.95	14	Hc Xh	1.60	23	Hc Hh	.99	32	Hh Xx	.32
6	Cc Hh	1.86	15	Hx Hh	1.57	24	Ch Xx	.86	33	Hh Xh	.27
7	Cx Xh	1.77	16	Cx Xx	1.28	25	Hc Hc	.75	34	Xc Hx	.17
8	Xc Xx	1.76	17	Xc Cx	1.24	26	Cc Hx	.71	35	Hc Cx	.15
9	Xc Ch	1.70	18	Hc Xx	1.22	27	Hx Hc	.65	36	Xh Xx	.12

Differences in relearning by the sub-groups from any one room can also be calculated in terms of the percentage saving in relearning. The original learning score minus the relearning score divided by the original score gives a value which expresses variation from a base, or original score. As the sub-groups in each room were equated on the basis of trials only, the percentage savings may reduce the reversals noted in the absolute scores. Also, such values show in a striking fashion the differences in relearning under the three temperature conditions. Table XIX gives the percentage saving on relearning for the nine groups.

As might be expected, the percentage saving, when learning is measured in terms of trials, errors or time, decreases as the rats are moved from rooms of lower to higher temperature. The rats from the hot room show the greatest saving when moved to rooms of lower temperature, as they have greater scores for original learning. Two reversals in the time scores still remain, but the differences are small.

Table XX regroups and summarizes the values presented in Table XIX. Here the groups relearning the maze in the same room are placed together. This is done in order to compare the rank of each sub-group, in terms of percentage saving, with the ranks in terms of absolute scores. In terms of percentage saving, the expected order will be HXC.

TABLE XIX

PERCENTAGE SAVING IN RELEARNING

	Trials				Errors				Time			
	Orig.	Rel.	Sav.	%Sav.	Orig.	Rel.	Sav.	%Sav.	Orig.	Rel.	Sav.	%Sav.
Cold Room Rats												
a. Left in C	20.2	7.1	13.1	64.85	118.0	17.4	100.6	85.29	4214	559	3655	86.73
b. Moved to X	20.0	9.8	10.2	51.00	163.2	11.8	131.4	80.51	4697	1090	3607	76.79
c. Moved to H	19.2	13.0	6.2	32.29	140.6	50.6	90.0	64.01	4021	1336	2685	66.77
Control Room Rats												
a. Moved to C	26.1	7.9	18.2	69.58	143.6	31.3	112.3	78.20	5235	702	4533	86.59
b. Left in X	26.3	11.3	15.0	56.92	159.3	40.0	119.3	74.89	4715	2009	2706	57.39
c. Moved to H	25.7	18.8	6.9	26.85	128.5	70.4	58.1	45.21	5169	1909	3260	63.07
Hot Room Rats												
a. Moved to C	35.4	8.2	27.2	76.86	254.5	28.9	225.6	88.64	8473	1019	7454	87.97
b. Moved to X	37.3	10.5	26.8	71.93	230.9	36.5	194.4	84.19	8025	748	7277	90.68
c. Left in H	37.5	16.5	21.0	56.00	255.6	47.6	208.0	81.38	8571	1715	6856	79.99

as the hot room rats, with the lowest level of performance, will be expected to show relatively greater gains in performance when placed in rooms of cooler temperatures.

For rats relearning in the cold room, the rank is HXC for trials, HCX for errors, and HCX for time. In the control room the corresponding values are HXC, HCX, and HCX. Sub-groups relearning in the hot room stand in the order HCX for trials, errors and time. Again, the control sub-groups lag behind in their expected position 7 of the 9 times. The hot room groups show the greatest percent improvement, standing first in every case. The possible basis for the control groups standing last is probably that advanced earlier in the discussion of the absolute values.

The differences in the percentage saving of groups of equal learning ability relearning the maze in the hot and cold rooms are interesting. Cold room sub-groups, relearning in the cold and hot rooms, have a difference in percentage saving of 31.9 for trials, 21.3 for errors, and 9.1 for time. Rats originally from the control room, relearning in the cold and hot rooms, have a difference of 42.7 % for trials, 33.0 % for errors, and 23.5 % for time. Corresponding values for hot room rats relearning in the hot and cold rooms are 20.9 %, 7.2 %, and 8.1 %. In general, the greatest difference in percentage saving for relearning in the extreme temperature conditions is found in the trial

TABLE XX

PERCENTAGE SAVING-RATS GROUPED BY ROOMS DURING RELEARNING

	Trials	Errors	Time
Cold Room			
a. from C	64.85	85.29	86.73
b. from X	69.58	78.20	86.59
c. from H	76.86	88.64	87.97
Control Room			
a. from C	51.00	80.51	76.79
b. from X	56.92	74.89	57.39
c. from H	71.93	84.19	90.68
Hot Room			
a. from C	32.29	64.01	66.77
b. from X	26.85	45.21	63.07
c. from H	56.00	81.38	79.99

scores, with the next greatest difference in the error scores. There was only a 9.1 % difference between the time scores for cold room rats relearning in the hot and cold rooms. The difference is 8.1 % for the hot room, and rises to 23.5 % for the control rats. Although large, this last value is the smallest for the differences in percentage saving for control rats relearning in the hot and cold rooms, when all three standards of learning are considered. The same general pattern, however, is found in most retention tests. Thus the differences noted are probably not a product of temperature alone.

Sex Differences in Maze Learning

In original learning tests, it was found necessary to drop some of the rats from the experiment. These rats, after repeated trials, consistently refused to run the maze. As might have been predicted, more rats were dropped from the hot room than from either of the other two. Interestingly enough, it was also noticed that more males than females in the hot room had to be removed. This fact suggested that there might be sex differences in maze performance under the extreme temperature conditions. Although Hellmer did not report any differences of this kind, he did indicate that the sex ratios for the second generations born in three rooms differed widely. Relatively more males were born in the cold room, and apparently more females in the hot.

Examination of the records show that 6 of the 9 rats dropped from the cold room were males. The same number were removed from the control room, 6 of which were males. In the hot room, however, 11 of the 12 rats dropped from the experiment were males. These facts suggest that the males seem to do relatively poorer in all three rooms, and especially so in the hot room.

Calculation of the mean trials, errors and time for original learning of the males and females in each of the rooms was next made. Table XXI gives these values. There is some indication that the males show better performance in the cold room; the females better in the hot room. In the cold room the males required 18.8 trials, while it took the females 21.1 trials. In the hot room the positions are reversed, with the males taking 42.0 trials to the females' 33.5. The same tendency is found in the time scores, but

TABLE XXI

MEAN TRIALS, ERRORS, AND TIME FOR MALES AND FEMALES IN EACH ROOM - ORIGINAL LEARNING

	Males				Females			
Group	No	Trials	Errors	Time	No	Trials	Errors	Time
Cold	25	18.8	128.4	4206	22	21.1	155	4713
Control	23	25.3	125.1	5054	23	26.6	161	5305
Hot	17	42.0	241.0	8941	30	33.5	247.2	7890

the males do somewhat better in terms of errors in the hot room than the females.

The reliability between the differences of the means for the trials of the males and females in each room was determined. Table XXII gives these values. As the critical ratios are all low, the differences may not be significant statistically. Since critical ratios for differences between errors and time are usually smaller than for trials, these values were not calculated in the present case.

TABLE XXII

RELIABILITY OF DIFFERENCES BETWEEN MEAN TRIALS - MALES AND FEMALES

Group	Mean	Diff.	σ Diff.	C.R.
Cold room males	18.8	2.3	2.29	1.0
females	21.1			
Control room males	25.3	1.3	3.89	.33
females	26.6			
Hot room males	42.0	8.5	5.14	1.65
females	33.5			

An additional check on the sex differences can be made by examining the relearning scores in each room, with all three sub-groups combined. These differences are shown in Table XXIII.

Although the males relearning in the cold room do better in terms of errors and time, they lag behind when trials are considered. There is no clear advantage in either direction in relearning in the control room. Males in the hot room again show the better performance on all three criteria. The trend in performance of the males and females was not the same in relearning as in the original learning, suggesting that there may be little significant difference in the ability of the sexes in the hot and cold rooms. However, this is only a preliminary examination, and conclusions should not be taken as final.

TABLE XXIII

MEAN TRIALS, ERRORS AND TIME FOR MALES AND FEMALES IN EACH ROOM - RELEARNING

	Males				Females			
Group	No	Trials	Errors	Time	No	Trials	Errors	Time
Cold	22	8.1	21.1	623.0	22	7.4	30.9	924.3
Control	19	11.0	33.9	1496.1	28	10.5	37.3	1123.9
Hot	22	15.5	53.1	1569.7	21	16.8	60.0	1753.5

Analysis of the Learning Curves

In order to compare the performance of the different groups of rats in the maze, it was necessary to use some method of making comparable the learning curves of all the rats. This must be done since different rats in each room mastered the maze after a different number of repetitions. Learning curves based on the average errors per trial would thus not be representative in the final portions of the learning process as only a very few animals would be included.

The procedure proposed by Vincent (68), with some modifications, has been used here. The three errorless runs, used as the criterion of learning, have been included in the total number of trials from which the Vincent curves were constructed. This was done to be consistent, as all standards of learning employed here include these trials. Although this does not follow the procedure suggested either by Loucks (40) or Hilgard (28) it is adequate for our purpose. Any Vincent curve presents, in a sense, an artificial picture. All that is desired here is some means of comparing the general progress in elimination of errors during the learning of the maze by the different groups of rats.

From the curves thus obtained, we note that there is little difference in performance between the rats learning in the cold and control rooms. Figure 9 shows that while the control room rats start with a greater number of average errors in the early tenth of the learning process, this group eliminates errors rapidly until the 5th tenth. From this point the control room rats are slightly behind the cold room rats. The learning curve for the hot room has the same general form as the other two curves, with the exception that it starts with greater average errors, and levels out at about the sixth tenth at a fairly high average error per tenth. This level is maintained until near the end of the learning.

Figure 10 gives the curves for relearning, combining all

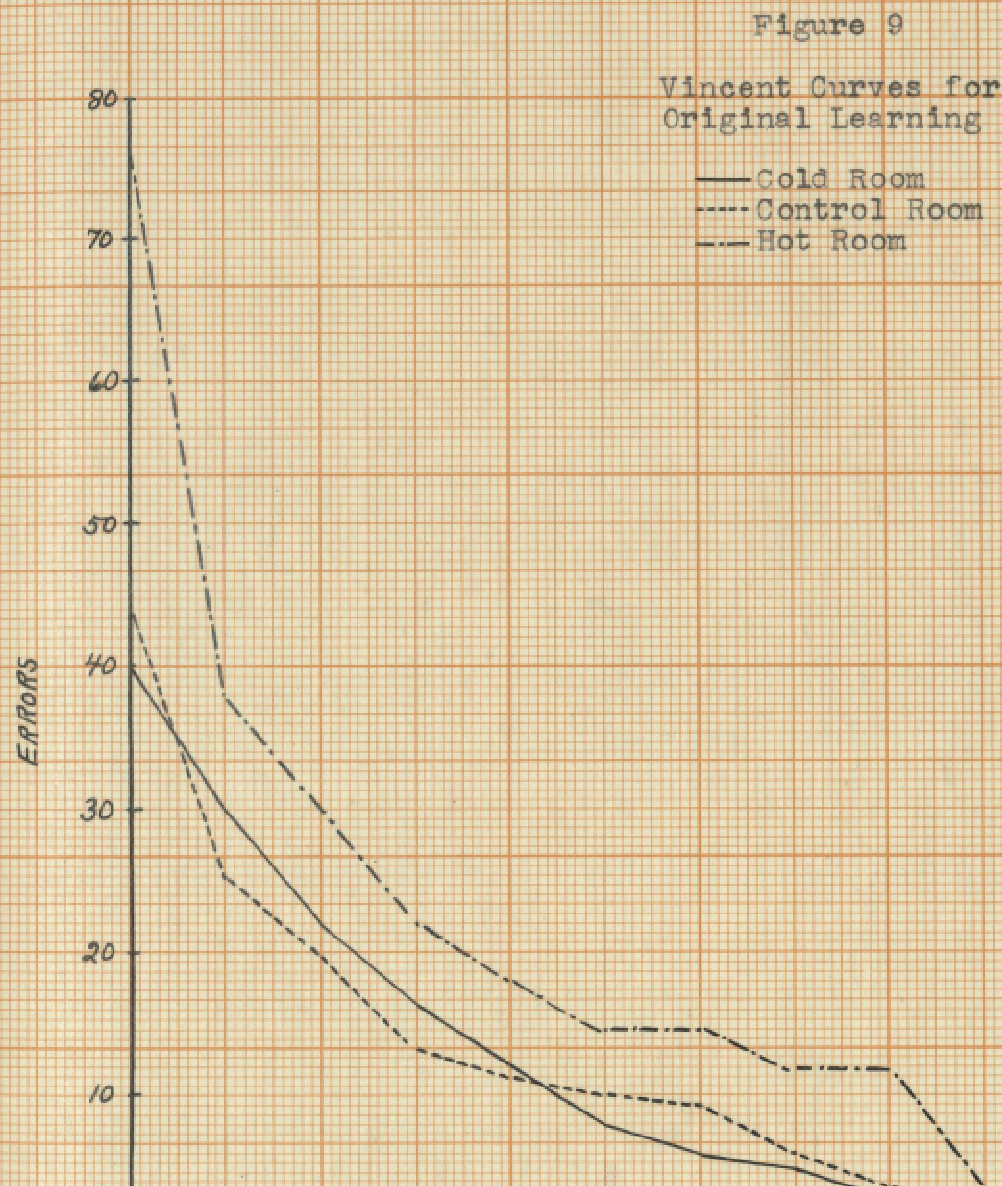


Figure 9
Vincent Curves for
Original Learning
Cold Room
Control Room
Hot Room
80
70
60
50
40
30
20
10
ERRORS
1
2
3
4
5
6
7
8
9
10
TENTHS

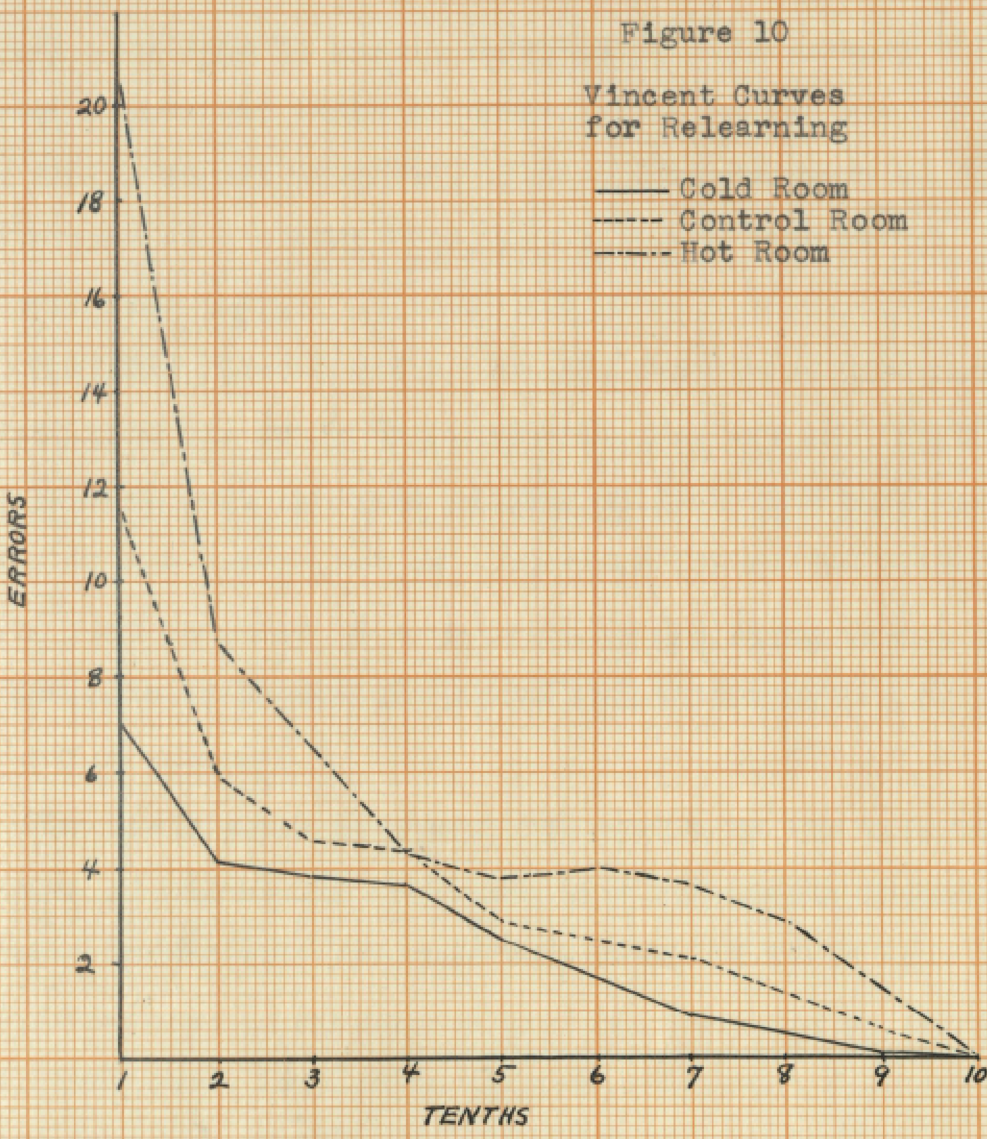


Figure 10
Vincent Curves
for Relearning
Cold Room
Control Room
Hot Room
ERRORS
20
18
16
14
12
10
8
6
4
2
1
2
3
4
5
6
7
8
9
10
TENTHS

sub-groups relearning in the same room, regardless of origin. The range of errors at first is large, but this diminishes rapidly until the mid-point of the curve. Here the groups from all three rooms make about the same average errors per tenth. After this point, however, the rats relearning in the hot room tend to show a decrease in performance, and the average errors per tenth increase. Rats in the cold room show fairly steady progress. The control groups also eliminate errors at a steady rate, but somewhat more slowly than the cold room rats.

Modified Vincent curves for all sub-groups relearning in each room are shown in Figures 11, 12, and 13. While they present much the same general picture that would be obtained if one considered only the mean trials for relearning, or the rank occupied by each group in the three rooms, they nevertheless delineate the course of relearning throughout the entire process.

The performance of groups relearning in the cold room is shown in Figure 11. Here the rats originally learning the maze in the cold room and relearning it there show the best performance. Average errors per tenth are at a low level throughout the entire learning process. The sub-groups from the control and hot rooms show about the same levels of performance, somewhat lower than the rats from the cold room.

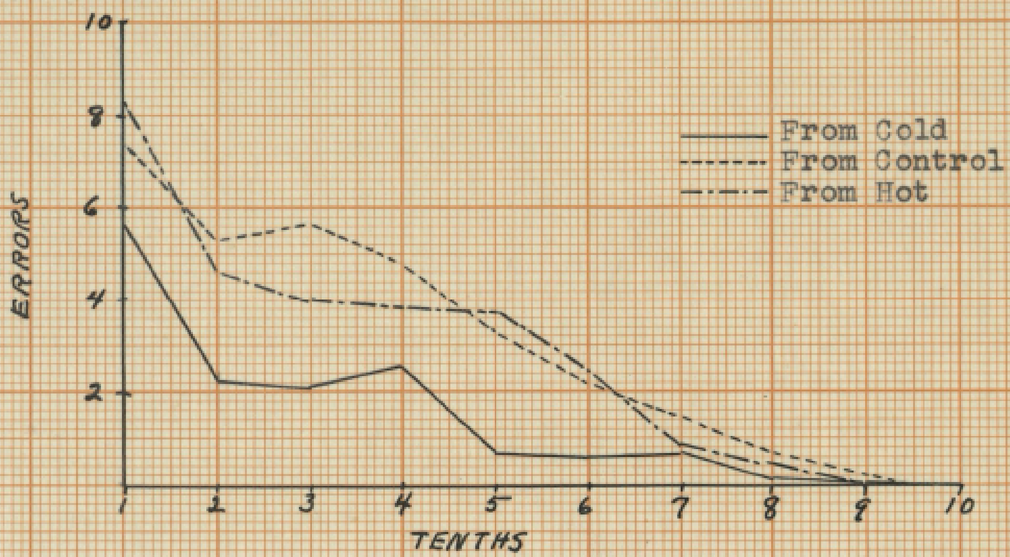


Figure 11

Vincent Curves for Rats Relearning in the Cold Room

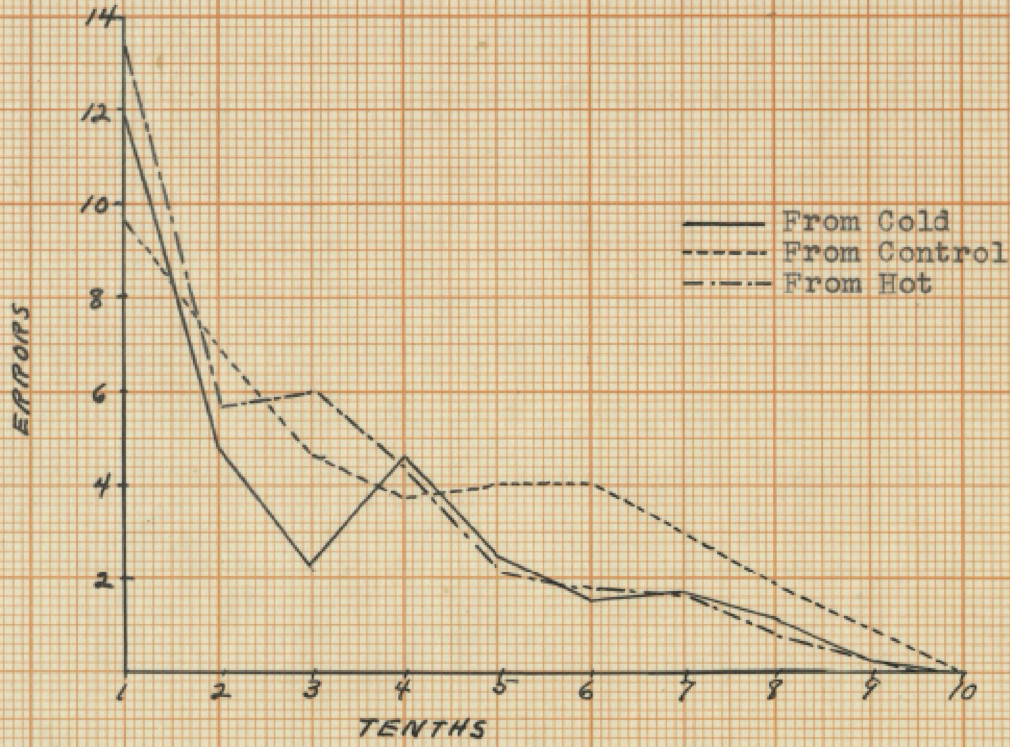


Figure 12

Vincent Curves for Rats Relearning in the Control Room

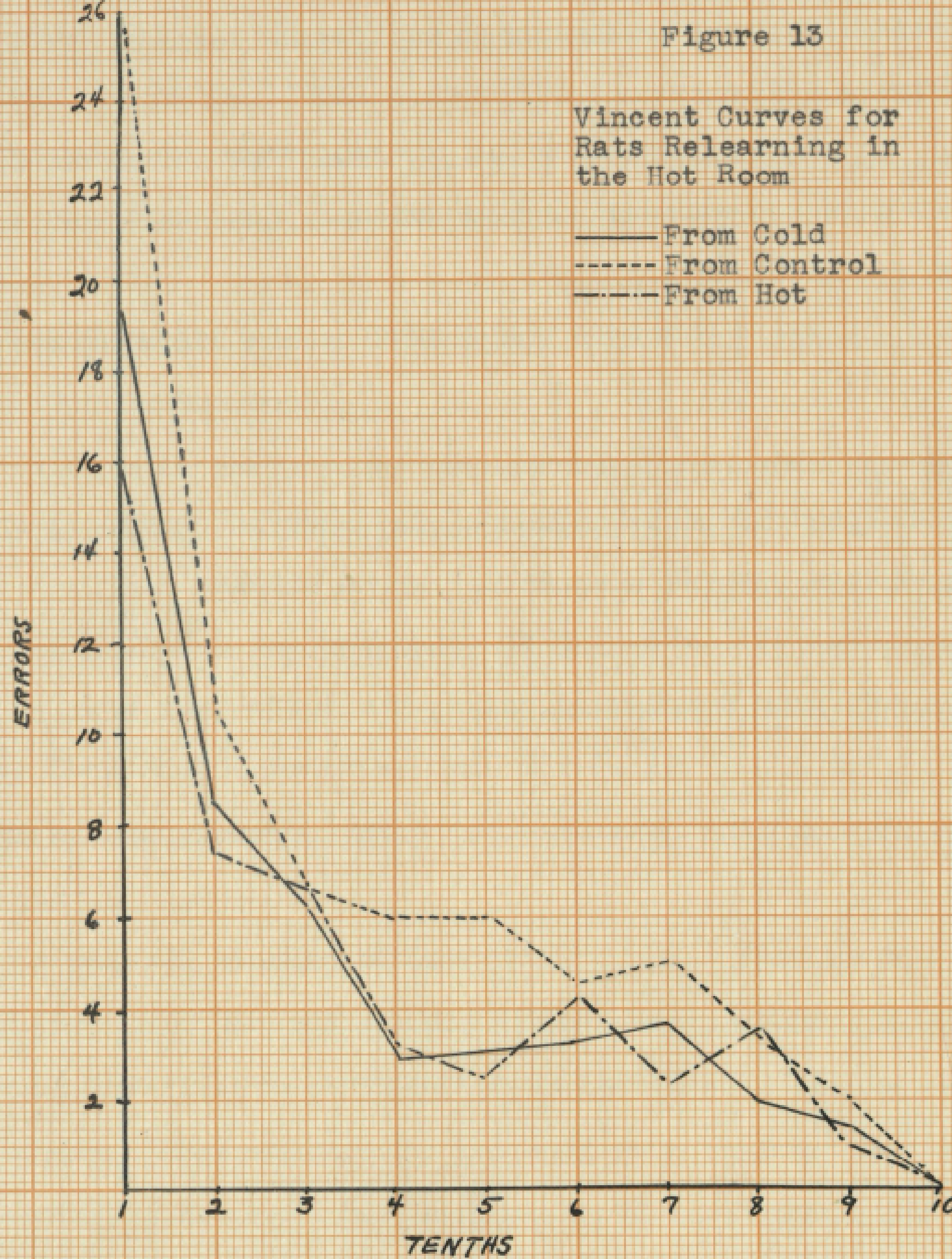


Figure 13
Vincent Curves for Rats Relearning in the Hot Room
From Cold
From Control
From Hot
26
24
22
20
18
16
14
12
10
8
6
4
2
ERRORS
1
2
3
4
5
6
7
8
9
10
TENTHS

Inspection of relearning curves from the control room (Figure 12) indicates that the sub-groups from the cold and hot rooms exhibit almost the same type of progress throughout the relearning. The curves diverge slightly during the first portions, but remain close together most of the time. While the sub-group from the control room starts with fewer average errors, there is a marked plateau from the 4th to 6th tenths which places this group behind the other two the remainder of the time.

Figure 13 for the hot room presents the same general picture. Here, however, the sub-group from the control room starts with a greater number of average errors, and remain in this position the remainder of the time. It is interesting to note that all 3 sub-groups in the hot room show a decided lack of progress from the 3rd or 4th tenth to the 7th tenth of the process. This is especially true for the cold and control rats.

A general picture of the rate of error elimination can be gained from the curves thus presented. Hellmer reported certain qualitative observations found to hold in the present study. Rats working in the cold room tend to show greater stability in their performance, both in learning and in relearning. Errors were eliminated gradually but consistently. This is reflected in the steady drop of the Vincent curve for that room. On the other hand, rats working in the hot room were quite erratic in their behavior both in learning and relearning, sometimes running the maze quickly and at other times failing to complete it in the period allowed. Progress in elimination of errors was unsteady, and after an initial period of improvement the rats seemed to show very little gain in learning for many trials. The plateaus in the curves for these rats are evidence of such behavior. It is interesting to note that in the case of relearning the curves become more variable, showing more instances of improvement followed by a decline, as one goes from the cold, through the control to the hot room.

The Obstruction Box Tests

Performance in the obstruction box was divided into four 5 minute periods, and the number of approaches, contacts and crossings were recorded for each interval. 47 rats were tested in the cold room, 53 in the control and 49 in the hot room. Performance of sub-groups within each room was also recorded. Table XXIV gives the mean values for approaches, contacts and crossings for the 9 sub-groups, as well as the means when the rats are grouped by rooms. Examination of the data from rats grouped by rooms in which they were tested reveals several tendencies. In each successive 5 minute period the number of approaches shows a slight tendency to increase from the cold through the control

TABLE XXIV

MEAN VALUES FOR APPROACHES, CONTACTS, AND CROSSINGS IN OBSTRUCTION BOX

	Rats tested in C				Rats tested in X				Rats tested in H			
	from C	from X	from H	all in C	from C	from X	from H	all in X	from C	from X	from H	all in H
	N=20	N=14	N=13	N=47	N=15	N=24	N=14	N=53	N=14	N=12	N=23	N=49
First 5 minutes												
approaches	4.1	3.4	3.2	3.6	4.7	5.9	4.0	5.1	5.3	5.6	4.6	5.0
contacts	9.2	5.0	9.2	7.9	6.7	8.1	9.7	8.1	7.2	7.0	6.7	7.0
crossings	4.0	7.8	8.1	6.3	3.5	1.9	4.4	3.0	1.4	2.4	2.0	1.9
Second 5 minutes												
approaches	2.8	3.3	2.9	3.0	3.9	3.9	3.6	3.9	6.8	5.8	3.4	4.5
contacts	.9	1.3	.7	1.0	.5	1.8	1.6	1.4	1.2	1.4	.8	1.1
crossings	5.3	6.8	10.2	7.7	2.9	2.3	5.4	3.3	.9	1.5	1.9	1.7
Third 5 minutes												
approaches	1.8	1.9	1.9	1.9	3.7	2.1	1.9	2.6	4.6	4.3	2.7	3.6
contacts	.8	.8	.4	.7	.5	1.3	1.1	1.2	1.6	.7	.3	.8
crossings	6.0	10.6	9.9	8.4	3.7	2.5	7.7	4.2	1.4	2.6	2.5	2.2
Fourth 5 minutes												
approaches	1.0	1.6	3.4	1.9	4.4	3.3	1.6	3.2	2.4	4.6	2.7	3.1
contacts	.3	.8	1.1	.7	.5	1.8	.7	1.1	1.4	.8	.4	.8
crossings	6.9	7.6	7.0	7.1	4.5	2.1	8.1	4.4	1.4	3.0	2.7	2.6
Totals												
approaches	9.6	10.3	11.2	10.2	16.7	13.6	11.3	14.6	17.7	19.8	13.3	16.1
contacts	11.3	7.8	11.4	10.3	8.1	12.9	13.1	11.6	11.6	9.9	8.3	9.6
crossings	22.7	34.7	35.2	29.5	14.5	7.5	25.6	14.8	5.1	9.3	9.5	8.1

to the hot room. In other words, more hot room animals failed to cross the grid. The number of contacts made by the cold and hot room rats was about equal, while the rats in the control room touched the grid more frequently. This means that in the cold room more approaches and contacts were converted to crossings while in the hot room there were few attempts to carry the action beyond the point of orientation toward the goal. The animals in the control room made more approaches that led to contacts than the rats in the hot room. Actual crossings indicate that rats tested in the cold room made the dash most frequently, with the control and hot rooms standing next in order.

When the approaches, contacts and crossings for each successive 5 minute period are examined separately, several trends can also be noticed. Considering all the rats tested in each room, we find a tendency to make most of the approaches in the first and second 5 minute periods, with a decline in the 3rd and fourth. The control rats act somewhat differently in that the greatest number of approaches are found in the second and last periods, and fewest in the third and first.

In all three rooms, more contacts are made in the first and second 5 minute periods, with the third and fourth periods coming next. The groups in the control room reverse this trend during the last two periods, however. Most of the crossings take place during the later trials, that is, in the third and fourth periods. The cold room is most active in the third interval while the other two rooms show the greatest number of crossings in the last period. Rats tested in the cold room show the fewest number of crossings in the first and fourth intervals, while those in the control and hot rooms cross less frequently in the first and second. As a rule, however, the same general pattern of activity in the five minute periods is displayed by the rats in all three rooms.

The standard deviations for the means for all rats tested in each room are given in Table XXV. The sigmas indicate that the greatest variability for approaches comes in different periods for each room. In the cold room, it is during the first and second periods. The first and fourth periods have the greatest variability in the control room, while it is the third and fourth in the hot room.

Contacts show almost the same order in all rooms, when variability of performance is considered. It is greatest usually in the first and second periods, and smallest in the third. On the other hand, total crossings are found to be most variable in different periods in the three rooms. The greatest spread of crossings is found in the third period in the cold room, during the fourth in the control room and in the first in the hot room. The smallest values were for the

TABLE XXV

MEANS, STANDARD DEVIATIONS, AND STANDARD ERRORS FOR EACH FIVE MINUTE PERIOD FOR ALL RATS TESTED IN EACH ROOM

	All rats tested in C			All tested in X			All tested in H		
	mean	σ	$\sigma/\sqrt{n}$	mean	σ	$\sigma/\sqrt{n}$	mean	σ	$\sigma/\sqrt{n}$
First 5 minutes									
approaches	3.6	9.15	1.33	5.1	3.64	.5	5.0	3.48	.5
contacts	7.9	5.54	.81	8.1	5.21	.72	7.0	4.22	.6
crossings	6.3	6.94	1.01	3.0	3.71	.5	1.9	6.23	.89
Second 5 minutes									
approaches	3.0	2.98	.43	3.9	3.55	.49	4.5	3.87	.55
contacts	1.0	3.43	.50	1.4	3.64	.50	1.1	1.19	.17
crossings	7.7	9.06	1.32	3.3	5.45	.75	1.7	3.36	.48
Third 5 minutes									
approaches	1.9	2.37	.35	2.6	3.14	.43	3.6	4.11	.59
contacts	.7	1.16	.17	1.2	2.27	.30	.8	2.12	.30
crossings	8.4	9.63	1.40	4.2	6.28	.86	2.2	4.28	.61
Fourth 5 minutes									
approaches	1.9	2.67	.39	3.2	4.41	.61	3.1	4.03	.58
contacts	.7	1.49	.22	1.1	2.83	.39	.8	1.75	.25
crossings	7.1	8.22	1.20	4.4	6.69	.92	2.5	3.96	.57
Totals									
approaches	10.2	8.80	1.28	14.6	12.20	1.67	16.1	12.90	1.84
contacts	10.3	6.70	.97	11.6	11.20	1.54	9.6	7.08	1.01
crossings	29.5	29.80	4.32	14.8	20.45	2.81	8.1	11.90	1.70

first period in the cold and control rooms, and the second period for the hot room.

Since the standard errors for many of the means are fairly large, there is doubt as to the reliability of some of these measures. In view of this fact, it seems quite probable that the temporal pattern of activity as well as the degree of variability of performance does not differ significantly in the three rooms.

Medians and ranges for the total number of approaches, contacts and crossings present about the same picture. Table XXVI gives these values. In general the medians are smaller than the means. This was to be expected, as many of the rats made a few if any crossings or contacts. This was especially true for crossings in the control and hot rooms. No consistent trends in the sizes of the ranges for the three rooms can be detected.

The data can next be examined to see if there are differences in performance between sub-groups within each room. Of all the rats tested in each room, one-third came originally from one of the three temperature conditions. Are there differences in behavior in the obstruction box that can be related to the room of origin, or that can be related to the trends found in the relearning of the maze? Values for approaches, contacts and crossings from Table XXIV can be used in determining the rank of each sub-group in each

TABLE XXVI

MEAN, MEDIAN, AND RANGES FOR TOTAL APPROACHES, CONTACTS AND CROSSINGS FOR THE NINE EXPERIMENTAL GROUPS.

	Rats tested in C				Rats tested in X				Rats tested in H			
	from C	from X	from H	all in C	from C	from X	from H	all in X	from C	from X	from H	all in H
Total Approaches												
Mean	9.6	10.3	11.2	10.2	16.7	13.6	11.3	14.6	17.7	19.8	13.3	16.1
Median	8.0	9.5	7.0	8.0	15.0	10.5	7.5	11.0	11.0	13.5	11.0	13.0
Range	0-34	0-28	0-32	0-34	0-29	0-44	0-51	0-51	4-38	2-51	1-53	1-53
Total Contacts												
Mean	11.3	7.8	11.4	10.3	8.1	12.9	13.1	11.6	11.6	9.9	8.3	9.6
Median	8.5	5.0	10.0	8.0	7.0	9.5	13.5	9.0	8.5	7.5	7.0	7.0
Range	3-22	1-20	0-23	0-23	0-18	3-79	0-25	0-79	0-38	1-28	1-21	0-38
Total Crossings												
Mean	22.7	34.7	35.2	29.5	14.5	7.5	25.6	14.8	5.1	9.3	9.5	8.1
Median	23.0	40.5	18.0	23.0	2.0	1.0	26.0	2.0	1.0	1.5	2.0	1.0
Range	0-78	0-94	0-109	0-109	0-61	0-51	0-68	0-68	0-43	0-35	0-39	0-43

TABLE XXVII

RANK OCCUPIED BY SUB-GROUPS IN EACH ROOM IN OBSTRUCTION BOX TESTS*

	Tested in C	Tested in X	Tested in H
First 5 min.			
approaches	C X H	X C H	X C H
contacts	(CH)X	H X C	C X H
crossings	H X C	H C X	X H C
Second 5 min.			
approaches	H C X	(CX)H	C X H
contacts	X C H	X H C	X C H
crossings	H X C	H C X	X H C
Third 5 min.			
approaches	(XH)C	C X H	C X H
contacts	(CX)H	X H C	C X H
crossings	X H C	H C X	X H C
Fourth 5 min.			
approaches	H X C	C X H	X H C
contacts	H X C	X H C	C X H
crossings	X H C	H C X	X H C
Totals			
approaches	H X C	C X H	X C H
contacts	H C X	H X C	C X H
crossings	H X C	H C X	H X C

* symbols in parenthesis indicate equal rank.

room. The rank can be expressed by using symbols to represent each sub-group and placing them in their order of magnitude. Thus in Table XXVII, the sequence CXH means that in any room the sub-group from the cold room stands first, that from the control room second, with the group from the hot room third.

There is some agreement in the number of approaches, contacts and crossings for the nine groups when the totals for the twenty minute test period are considered. Rats from the hot room when tested in the cold room show the greatest number of approaches, contacts and crossings. A similar group in the control room also stands first in contacts and crossings. In the hot room, the sub-group remaining in the hot room has the most crossings. However, the order of activity is not so consistent in each room during the four 5 minute periods, as compared with the totals for the 20 minute period. The order of crossings during these sub-periods is the most regular, as compared with approaches and contacts. In the cold room the order is HXC the first 10 minutes, and XHC the last half. Crossings in the control room are in the order HCX for all 5 minute periods, and in the order XHC for all periods in the hot room. The sequence of approaches and contacts is more confused, with the cold room sub-groups highest in number, with the H and X groups in second and third positions. An outstanding exception occurs in the case of contacts in the control room. Here the cold room sub-group is last in all 4 periods.

The sigmas and standard errors for the sub-group totals are given in Table XXVIII. Although there are a few means not sufficiently larger than the standard errors to indicate complete reliability, in general the differences are great enough to be satisfactory.

Critical ratios for the differences between the means of approaches, of contacts, and of crossings for the sub-groups tested within the same room are given in Table XXIX. Only the totals for the twenty minute period are here used. All of the ratios are small, indicating that statistically the differences are probably not significant. Differences between the highest and lowest values of groups in the same room are greatest for crossings. Only two of the 27 ratios are above a C.R. of 2, however. One of these is the control room contacts, as between cold and hot room sub-groups, and one is in the control room crossings as between control and hot room sub-groups. Over one-half of the ratios are below 1. Evidently the rats as a whole show much the same performance in a given room regardless of the temperature of their room origin.

Critical ratios for the differences between means of performances of the three groups as wholes in each 5 minute interval are given in Table XXX. Here only the total approaches, contacts, and crossings are considered. The ratios are much higher than when the sub-groups were considered separately, exceeding the standard of 3 in some instances.

TABLE XXVIII

MEANS, STANDARD DEVIATIONS, AND STANDARD ERRORS FOR THE TOTAL APPROACHES, CONTACTS AND CROSSINGS FOR THE NINE EXPERIMENTAL GROUPS

		Approaches			Contacts			Crossings		
	N	Mean	σ	$\sigma/\sqrt{n}$	Mean	σ	$\sigma/\sqrt{n}$	Mean	σ	$\sigma/\sqrt{n}$
Rats tested in C										
a. from C	20	9.6	6.56	1.47	11.3	6.33	1.42	22.7	23.47	5.25
b. from X	14	10.3	8.83	2.36	7.8	6.13	1.64	34.7	28.20	7.54
c. from H	13	11.2	10.75	2.99	11.4	7.12	1.98	35.2	36.70	10.20
Rats tested in X										
a. from C	15	16.7	9.83	4.37	8.1	4.02	1.01	14.5	21.87	5.47
b. from X	24	13.6	13.04	2.67	12.9	14.87	3.04	7.5	12.50	2.55
c. from H	14	11.3	12.64	3.38	13.1	7.73	2.07	25.6	24.98	6.68
Rats tested in H										
a. from C	14	17.7	10.90	2.91	11.6	9.32	2.49	5.1	11.30	3.02
b. from X	12	19.8	16.30	4.71	9.9	7.34	2.12	9.3	12.05	3.48
c. from H	23	13.3	11.50	2.40	8.3	4.68	.98	9.5	12.20	2.54

TABLE XXIX

CRITICAL RATIOS FOR DIFFERENCES BETWEEN GROUPS IN SAME ROOM IN APPROACHES, CONTACTS AND CROSSINGS FOR TWENTY MINUTE PERIOD

Group	Approaches				Contacts				Crossings			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
Cc Xc	9.6 10.3	.7	2.78	.25	11.3 7.8	3.5	2.16	1.62	22.7 34.7	12.0	9.18	1.30
Cc Hc	9.6 11.2	1.6	3.33	.48	11.3 11.4	.1	2.43	.41	22.7 35.2	12.5	11.50	1.09
Xc Hc	10.3 11.2	.9	3.81	.24	7.8 11.4	3.6	2.56	1.40	34.7 35.2	.5	12.70	.04
Cx Xx	16.7 13.6	3.1	5.12	.60	8.1 12.9	4.8	3.20	1.53	14.5 7.5	7.0	6.03	1.16
Cx Hx	16.7 11.3	5.4	5.52	.99	8.1 13.1	5.0	2.30	2.17	14.5 25.6	11.1	8.63	1.29
Xx Hx	13.6 11.3	2.3	4.30	.53	12.9 13.1	.2	3.67	.03	7.5 25.6	18.1	7.15	2.53
Ch Xh	17.7 19.8	2.1	5.54	.38	11.6 9.9	1.7	3.27	.52	5.1 9.3	4.2	4.61	.91
Ch Hh	17.7 13.3	4.4	3.77	1.17	11.6 8.3	3.3	2.67	1.24	5.1 9.5	4.4	3.95	1.11
Xh Hh	19.8 13.3	6.5	5.28	1.23	9.9 8.3	1.6	2.33	.69	9.3 9.5	.2	4.31	.05

TABLE XXX

CRITICAL RATIOS OF THE DIFFERENCES BETWEEN MEANS OF APPROACHES, CONTACTS AND CROSSINGS FOR ALL RATS IN EACH ROOM, FOR EACH 5 MINUTE PERIOD

Group	Approaches				Contacts				Crossings			
	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.
First 5 minutes												
All in C	3.6	1.5	1.42	1.06	7.9	.2	1.09	.2	6.3	3.3	1.13	2.92
" " X	5.1				8.1				3.0			
All in C	3.6	1.4	1.42	.99	7.9	.9	1.01	.89	6.3	4.4	1.35	3.26
" " H	5.0				7.0				1.9			
All in X	5.1	.1	.70	.14	8.1	1.1	.94	1.17	3.0	1.1	1.02	1.08
" " H	5.0				7.0				1.9			
Second 5 minutes												
All in C	3.0	.9	.65	1.38	1.0	.4	.71	.62	7.7	4.4	1.52	2.89
" " X	3.9				1.4				3.3			
All in C	3.0	1.5	.69	2.32	1.0	.1	.53	.19	7.7	6.0	1.40	4.28
" " H	4.5				1.1				1.7			
All in X	3.9	.6	.73	.82	1.4	.3	.53	.57	3.3	1.6	.89	1.80
" " H	4.5				1.1				1.7			

TABLE XXX (CONTINUED)

Group	Approaches				Contacts				Crossings			
	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.
Third 5 minutes												
All in C	1.9	.7	.56	1.25	.7	.5	.36	1.39	8.4	4.2	1.64	2.56
" " X	2.6				1.2				4.2			
All in C	1.9	1.7	.69	2.46	.7	.1	.36	.28	8.4	6.2	1.53	4.05
" " H	3.6				.8				2.2			
All in X	2.6	1.0	.73	1.37	1.2	.4	.45	.89	4.2	2.0	1.05	1.90
" " H	3.6				.8				2.2			
Fourth 5 minutes												
All in C	1.9	1.3	.72	1.80	.7	.4	.45	.89	7.1	2.7	1.50	1.80
" " X	3.2				1.1				4.4			
All in C	1.9	1.2	.70	1.70	.7	.1	.33	.30	7.1	4.5	1.33	3.38
" " H	3.1				.8				2.6			
All in X	3.2	.1	.84	.12	1.1	.3	.46	.65	4.4	1.8	1.08	1.68
" " H	3.1				.8				2.6			
Totals												
All in C	10.2	4.4	2.10	2.10	10.3	1.3	1.82	.71	29.5	14.7	5.15	2.85
" " X	14.6				11.6				14.8			
All in C	10.2	5.9	2.24	2.63	10.3	.7	1.40	.50	29.5	21.4	4.64	4.60
" " H	16.1				9.6				9.1			
All in X	14.6	1.5	2.48	.60	11.6	2.0	1.84	1.09	14.8	6.7	3.28	2.04
" " H	16.1				9.6				8.1			

The greatest differences and reliabilities are usually found between cold and hot room groups. In most cases the performance of the control and hot room is very much alike. As indicated by the critical ratios, the greatest reliability of the differences is found when crossings are considered, with the least reliability for approaches. The differences between the means for the total crossings for all rats tested in each room are fairly large, and the reliability as measured by the critical ratios is somewhat better. Here again, the greatest difference is between the hot and cold rooms, and the corresponding critical ratio is 4.6. On a room by room basis, the crossings for the entire test period seem to show a real difference.

The Relation Between Relearning Scores and Grid Crossings

Considering the performance of all rats in each room, it was found that the rats in the cold room both learned and relearned the maze most quickly. Rats in the control room were in second place, while those in the hot room needed the most trials for mastery of the maze. This same order was repeated when grid crossings for all rats in each room were considered. On a room by room basis, there is some relation between learning, relearning and grid crossings. However, let us take the next step, and see if the same relation can be found within rooms. That is, within each room, do those rats which relearn the maze most rapidly also tend to make the most crossings on the grid? The greatest similarities probably would exist between sub-groups within any one room. The background of temperature changes is the same, and the performance should be more nearly the same in both relearning and grid tests. The coefficients of correlation between the trials on relearning and the number of grid crossings in the twenty minute test period were determined, using the rank difference method. Table XXXI gives these values.

TABLE XXXI

COEFFICIENTS OF CORRELATION BETWEEN RANK IN RELEARNING (TRIALS) AND GRID CROSSINGS BY SUB-GROUPS

	Cold Room	Control Room	Hot Room
From C	-.15	+.15	+.44
From X	-.06	-.05	-.06
From H	+.36	-.12	-.44

All the coefficients are low, with more negative than positive values. The largest, +.44 for the performance of the cold room rats in the hot room, is balanced by the lowest, -.44 for the hot room rats in the hot room.

Combining the sub-groups in the same room and using the Pearson product moment method, even smaller coefficients of correlation were obtained. For the cold room, $r = +.06 \pm .1$; for the control room, $r = -.072 \pm .1$; and for the hot room, $r = -.303 \pm .1$. This indicates that in each room, <u>the most rapid learners and the slowest learners tend to cross the grid</u>

<u>about an equal number of times.</u>

This conclusion is substantiated when the data are combined by still another method. As was mentioned previously, some of the rats in each room were removed from the original learning series because they failed to master the maze under the prescribed conditions. These rats were given tests in the obstruction box. Let us assume that refusal to run the maze can be interpreted as isolating those of lower ability, and compare their grid scores with groups of known greater ability--in terms of successful completion of the maze.

In the cold room, the average number of crossings by the rats dropped from the learning tests was 27.1. The average for all other rats tested in the cold room was 29.5. Values for the sub-groups in the cold room that completed the maze were (a) from the cold room, 22.7; (b) from the control room, 34.7; and (c) from the hot room, 35.2. The cold room rats that both learned and relearned the maze in the cold room thus show fewer grid crossings than do the rats dropped from the maze during the first learning tests.

Eliminated rats from the control room crossed the grid an average of 9.8 times in the 20 minutes. The average for all rats tested in the control room was 14.8 crossings. The crossings, by sub-groups, were; (a) from C, 14.5; (b) from X, 7.5; and (c) from H, 25.6. Again the rats dropped from the original experiment in the control room cross more frequently than rats learning and relearning the maze in the control room.

The eleven rats dropped from the hot room crossed the grid 6.7 times as contrasted with 8.1 for all rats in that room. The sub-group from the cold room, relearning in the hot, averaged 5.1 crossings; from the control room this number was 9.3; and from the hot room, 9.5. The only time that the discarded rats do not show more grid crossings than rats left in the original room is found in the case of the hot room.

Rate of Growth and Maze Performance

Is rate of growth at the time of maze running a factor that may influence maze performance? The same period of food deprivation may produce different effects on rats growing at different rates. Animals adding weight rapidly may be "hungrier" after the same period of food deprivation than rats adding weight more slowly. Differences in the learning scores might then result.

In the original <u>learning</u> tests, rats in the cold room grew most rapidly and learned the maze most quickly. The control and hot room rats show very nearly the same rate of growth, but there are marked differences in maze learning. At the time of the maze tests there is a slight difference in rate of growth in favor of the control room. If rats growing faster lose weight faster during the same learning period, then the loss in weight curves and growth curves should correspond. But the curves <u>are not</u> similar.

In order to see if there is any relation between these two factors in the <u>relearning</u> tests, growth curves for the groups of rats starting in different rooms but ending in the same room have been drawn. In Figure 14 the blue line represents the rate of growth of rats started in the cold room and retested there after original learning. The green line represents the rate of growth for rats started in the control room, but moved to the cold room after the first learning tests at about the twelfth week. Rats started in the hot room but moved to the cold room for relearning tests are represented by the red line. The same symbols in Figures 15, and 16 show that the growth curves for the groups in the control and hot rooms.

Of the three groups relearning in the cold room, the rats kept in that room throughout the experiment continue to grow most rapidly. They also relearned the maze more rapidly than other groups in that room. The group from the control room is second in rate of growth and speed of learning. The hot room group stands third in both measures.

In the control room (Figure 16), the sub-group from the cold room again shows the most rapid growth. The rats from the hot room are below those from the control room most of the

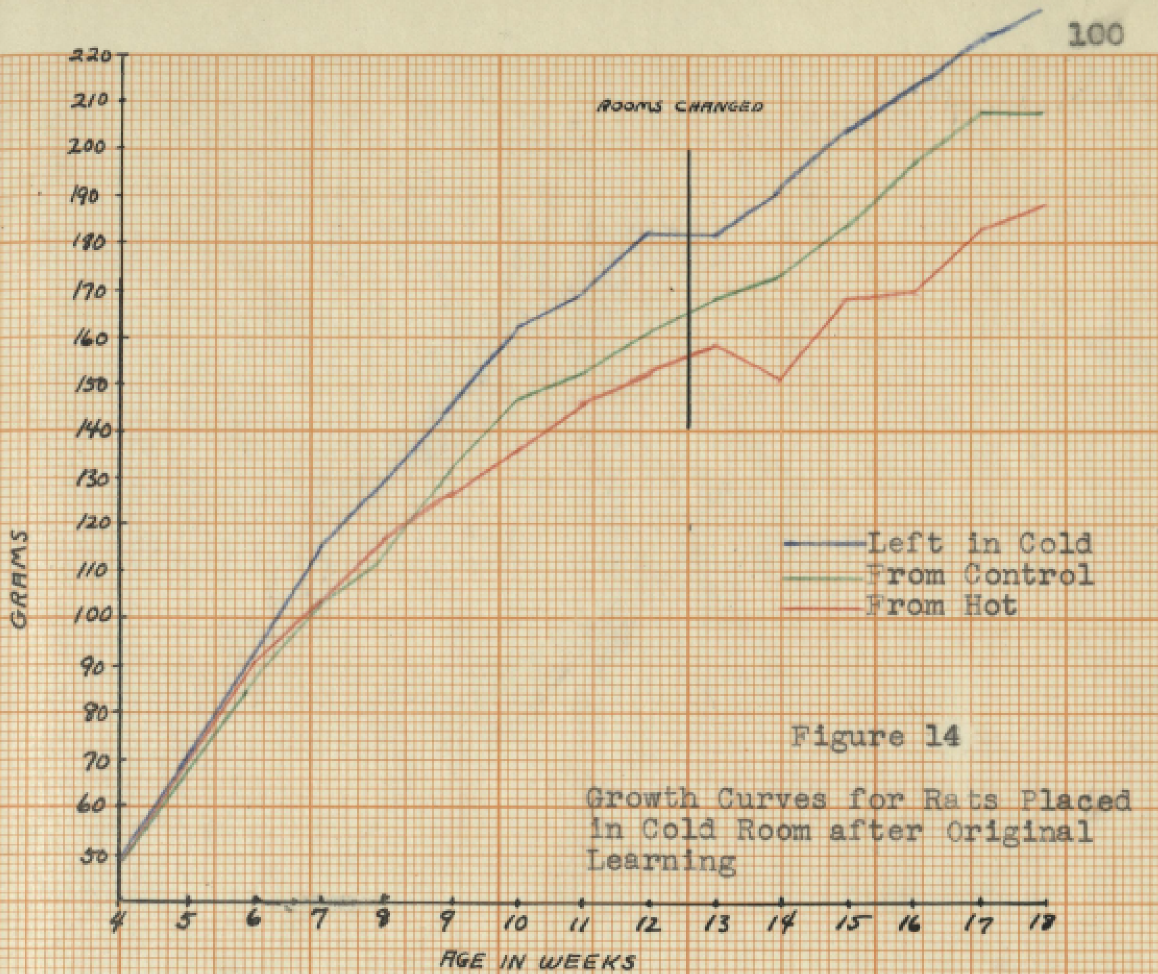


Figure 14

Growth Curves for Rats Placed in Cold Room after Original Learning

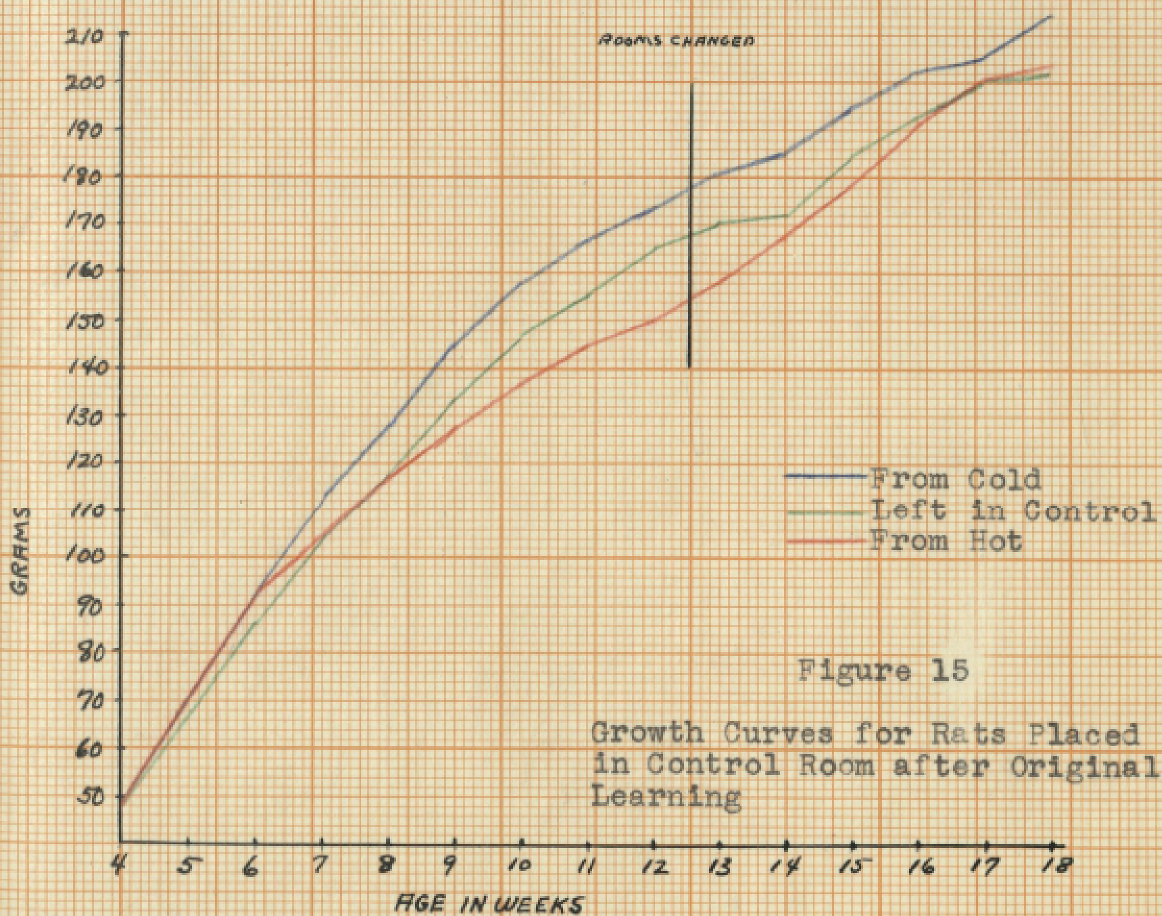


Figure 15

Growth Curves for Rats Placed in Control Room after Original Learning

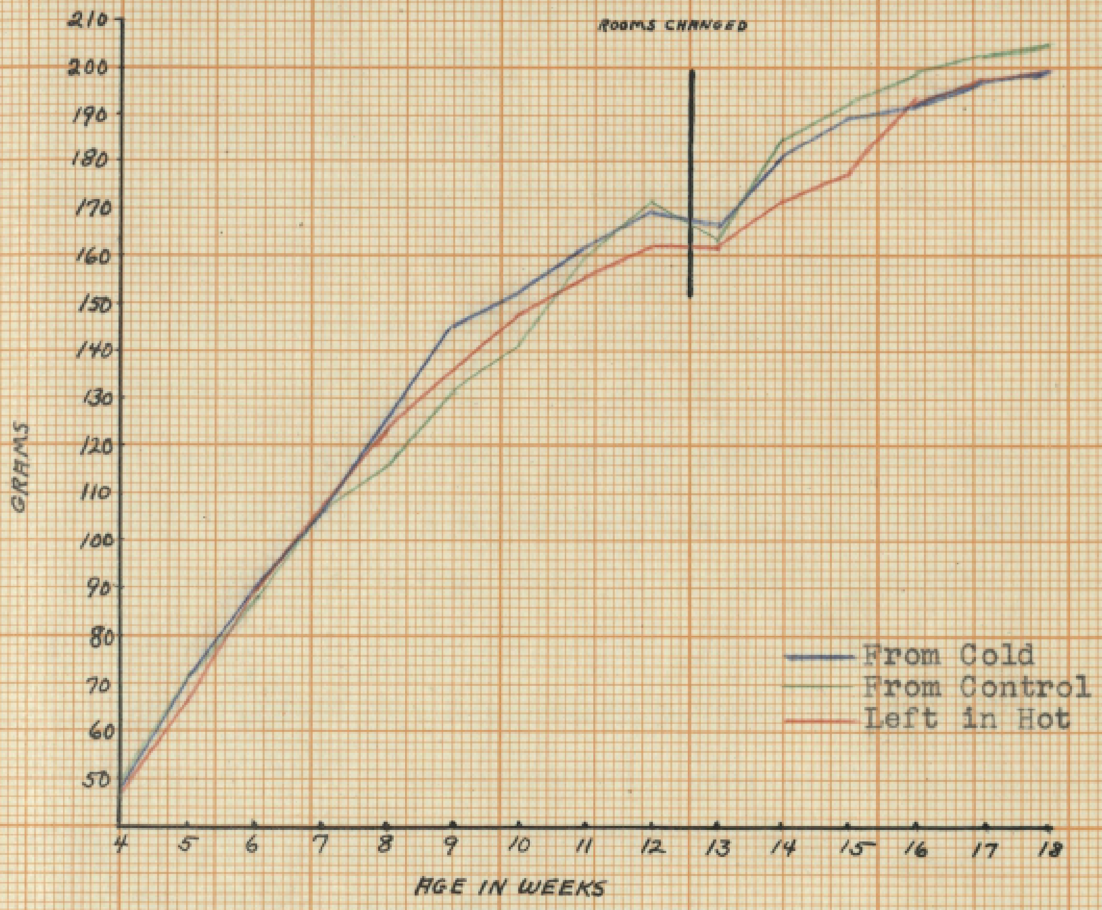


Figure 16

Growth Curves for Rats Placed in Hot Room after Original Learning time, but at the end of the 18th week stand slightly above the average weight of the control room group. The difference in weight is almost zero, however. The relearning order in the control room is C H X.

Figure 16 shows the growth curves for the sub-groups ending in the hot room. Although there is little difference in average weight at the 18th week, the control sub-groups are slightly heavier, and grow more rapidly during the last four weeks. The hot room rats show the slowest rate of growth until the last three weeks, when they are just above the cold room rats. The relearning order in this room is C H X, just opposite the order of growth during the 16th to 18th weeks.

The evidence for a relation between rate of growth and learning ability is inconclusive. Only in the cold room are marked growth differences found in the 3 sub-groups, but it is in this room that the smallest differences in relearning trials are found. The largest differences in relearning scores are found in the hot room, where the growth curves are the most nearly alike, for all three sub-groups. There does not seem to be any clear relation between rate of growth and maze performance in relearning.

Performance and Weight Losses

A second method was used in an attempt to clarify the relative importance of the intelligence and motivational factors involved in learning in the three rooms. Rats living in the higher temperatures have a lower rate of metabolism. Djelineo (18) has found marked differences for rats living under different temperatures. Less food is no doubt required to maintain body heat, and the same period of starvation used in all three rooms may affect the rats in each room differently. Because of the lowered metabolism, animals living and working in the hot room may be less hungry, and thus learn more slowly. In an attempt to measure this factor, daily weight records were kept for all rats during learning, relearning and grid tests. While it is not the intention here to infer that "hunger" is equal to the loss of weight, or that hunger varies in the same fashion as motivational factors do, the loss of weight seemed to be about the only objective measurement that could be made under the present experimental conditions. It should have something to do with the different degrees of apparent motivation in the different rooms. But the problem is complicated by the fact that the same <u>absolute</u> loss of weight is not a fair measure of the differences in each room. To correct for this, the <u>percent</u> of the original weight retained in each room has been calculated.

First, the number of rats in each room showing a loss in weight from the previous days during original learning was determined. Figure 17 indicates the trend in each room. In the cold room all of the rats lose weight the first two days, and after that some show a gain in weight the next few days. The curve for the hot room shows that more rats tend to gain weight during maze running than in the cold room. The rats in the control room show an irregular trend. For the first few days the number gaining weight is between that of the cold and hot rooms. The fourth and fifth days show a decided increase in the number gaining weight, but this trend then reverses and from the sixth to the ninth days of maze running, more and more of the rats lose weight each day.

Figure 18 shows the average loss of weight in grams each day of maze running. Rats in the cold room lose more weight at first, and tend to reach a level of about zero weight-loss more slowly than the rats in the hot or control rooms. The hot and control room curves for average loss of weight each day follow each other closely until the curve for the control room goes below that of the cold room, and then rises on the tenth day. In the hot room there is an average gain in weight from the seventh to ninth days.

If loss of weight each day of maze running is related directly to maze learning, these curves are not in the expected order. For the first five days the predicted order is followed. That is, rats losing the most weight each day show the most rapid progress in the maze. After the fifth

Figure 17 Percent of Rats Losing Weight Each Day of Maze Running Original Learning

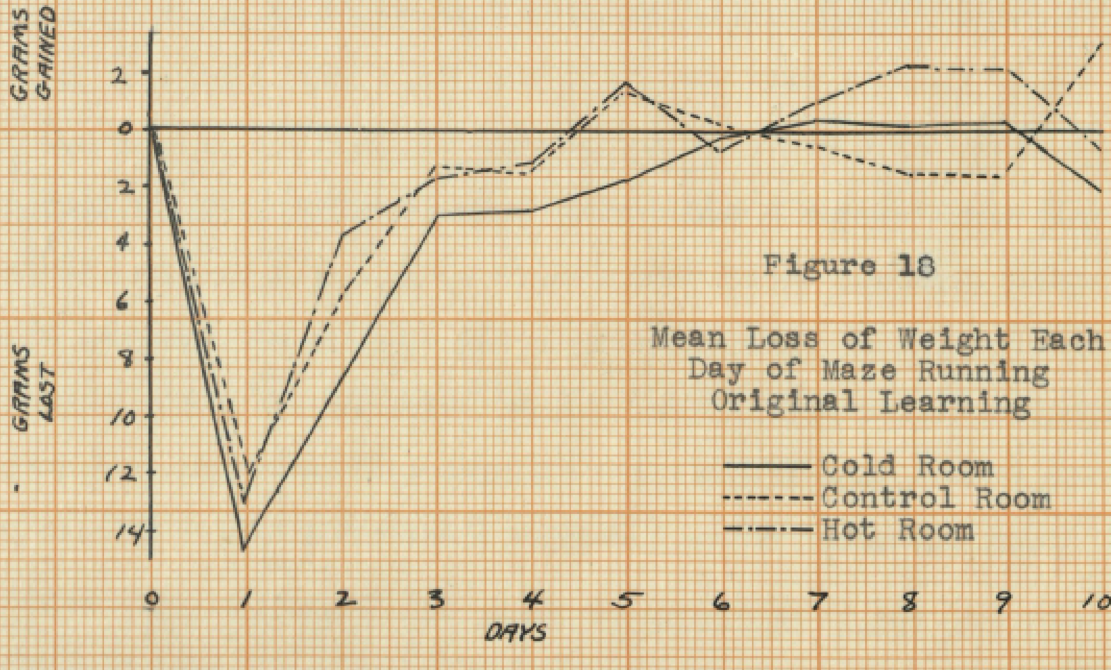


Figure 18

Mean Loss of Weight Each Day of Maze Running Original Learning day discrepencies appear. Losses for the control and cold rooms are opposite those of the first five days. From the seventh to ninth days there are still considerable numbers of rats running in the control room, 17 on the 7th, 16 on the 8th, and 10 on the 9th, while in the cold room the number running on the corresponding days was 12, 7, and 6. It may be possible that there are not enough rats in the cold room still running on these days to give a representative picture. Possibly a greater portion of these rats are exceptionally poorer learners than is the case of the rats running on these days in the control room. If this explanation is true, then the reversal noted above may not be important. The hot room rats seem to lose the least weight and begin to show an average gain each day more rapidly than the other two groups.

The mean percent of original weight retained each day of maze running is shown by Figure 19. Measured by this method, the cold room rats show a steady loss of weight until the fourth day with stabilization at about 85 % of their original weight, followed by a second short drop. Again the control and hot room curves follow each other closely, showing a tendency to gain in the percent original weight retained. As in the absolute weight losses, the order of learning on the one hand and, curves indicating weight losses on the other, do not correspond when all three rooms are considered. The marked differences in learning in the hot and

Figure 19

Percent Original Weight Retained Each Day of Maze Learning - First Learning

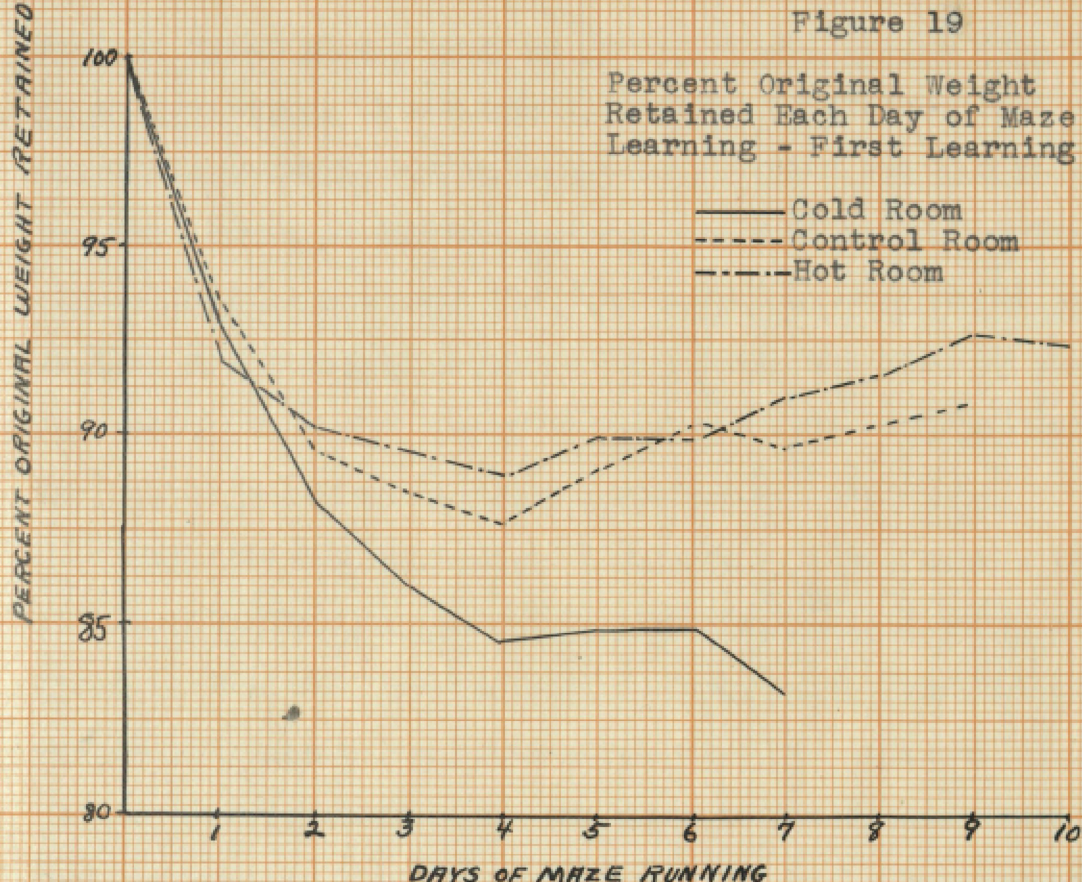
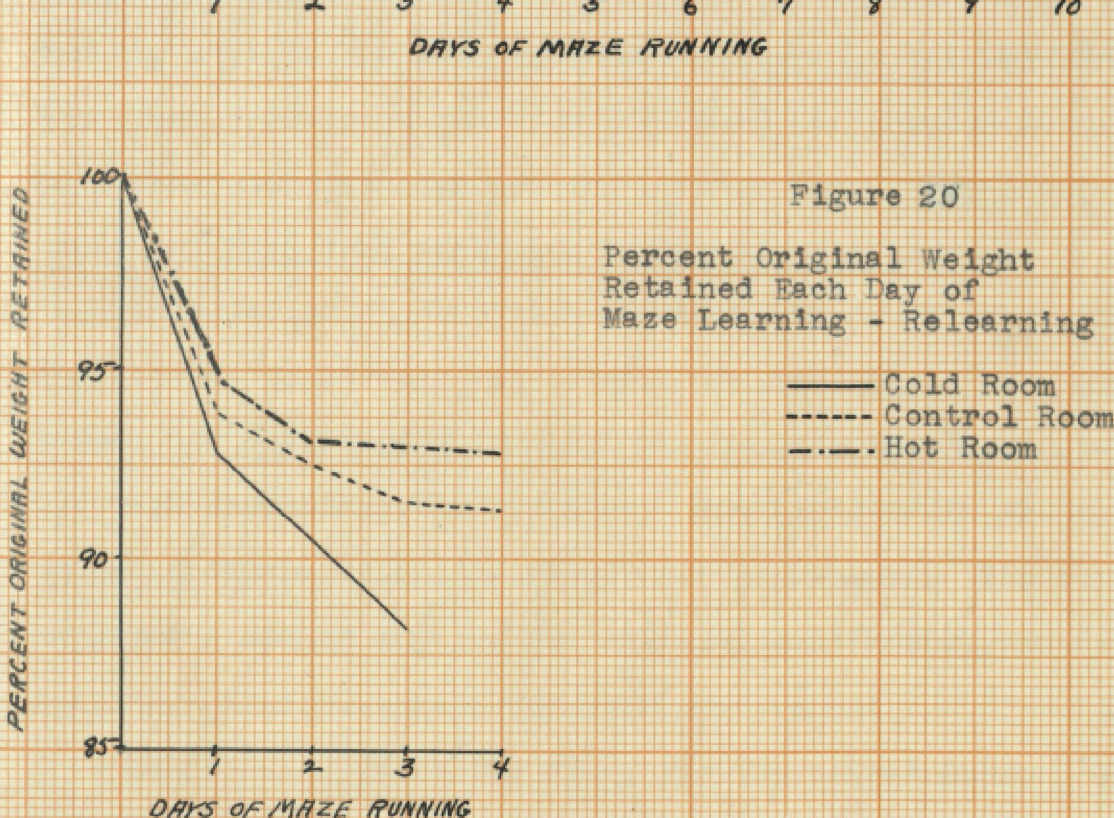


Figure 20

Percent Original Weight Retained Each Day of Maze Learning - Relearning



control rooms do not show up in the weight loss curves for these two rooms. Table XXXII, however, indicates that these means are probably not reliable after about the fourth day. The same measures for the percent original weight retained (Table XXXIII) indicate that the means are many times greater than the standard errors. Increasing the size of the index number, however, probably does not alter the fact that the weight measures should be considered cautiously.

Critical ratios for the differences between mean absolute weight loss and percentage original weight retained are given in Tables XXXIV and XXXV. These values are not high enough to indicate that the differences in absolute weight losses are very reliable. The highest ratios are found usually between the cold and control rooms or the cold and hot rooms. Although there were decided differences in maze performance between the hot and control rooms, this fact would not have been predicted by the weight losses.

In considering the loss of weight during original learning, it was found that the rats in the cold room lost most weight per day of maze running, and that these rats showed the best performance in the maze. The relation in the case of the control and hot rooms was not so obvious. The same comparison can be made in the relearning situation, as daily weight records were kept for this performance.

Table XXXVI gives the means for the weight losses, by

TABLE XXXII

MEAN WEIGHT LOSSES EACH DAY OF MAZE RUNNING FOR EACH ROOM

	Cold Room				Control Room				Hot Room			
Day	N	Mean	σ	σ/√n	N	Mean	σ	σ/√n	N	Mean	σ	σ/√n
1	34	14.3	5.47	.94	34	12.3	4.37	.75	39	13.2	4.84	.78
2	40	8.3	16.1	2.25	42	5.8	3.86	.59	44	3.7	4.69	.71
3	39	2.9	4.19	.67	41	1.4	3.74	.58	45	1.6	4.62	.69
4	35	2.8	3.37	.57	37	1.4	4.2	.69	37	1.2	3.08	.51
5	31	1.8	4.79	.86	30	-1.3	4.68	.85	34	-1.5	4.06	.70
6	22	.3	2.95	.63	24	- .1	5.17	1.06	30	.7	3.7	.68
7	12	.5	4.74	1.37	17	.4	5.58	1.35	23	-1.2	5.38	1.12
8					16	1.4	3.76	.89	20	-2.3	4.69	1.05

The - sign indicates gain in weight in weight loss tables.

TABLE XXXIII

MEAN PERCENT ORIGINAL WEIGHT RETAINED EACH DAY OF MAZE RUNNING FOR EACH ROOM

	Cold Room				Control Room				Hot Room			
Day	N	Mean	σ	σ/√n	N	Mean	σ	σ/√n	N	Mean	σ	σ/√n
1	34	92.7	2.54	.44	34	93.1	2.48	.43	39	92.2	3.11	.5
2	40	88.0	3.62	.62	42	89.4	3.07	.53	44	90.0	2.84	.46
3	39	86.0	4.5	.78	41	88.5	2.90	.51	45	89.4	3.68	.6
4	35	84.6	5.07	.90	37	87.7	4.28	.78	37	88.9	4.11	.72
5	31	84.9	5.56	1.13	30	89.0	4.08	.78	34	89.8	5.4	.98
6	22	85.0	5.74	1.32	24	90.2	5.21	1.14	30	89.7	5.92	1.14
7	12	83.2	5.7	1.72	17	89.8	5.33	1.33	23	91.0	7.14	1.64
8					16	90.3	5.5	1.47	20	91.5	6.44	1.61

TABLE XXXIV

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN MEAN LOSS OF WEIGHT EACH DAY OF MAZE RUNNING IN ORIGINAL LEARNING

Group	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.
	First Day				Fourth Day				Seventh Day			
C	14.3	2.0	1.20	1.67	2.8	1.4	.89	1.57	-.5	.9	1.92	.47
X	12.3				1.4				.4			
C	14.3	1.2	1.22	.98	2.8	1.6	.76	2.11	-.5	.7	1.77	.40
H	13.2				1.2				-1.2			
X	12.3	.9	1.08	.83	1.4	.2	.86	.23	.4	1.6	1.75	.91
H	13.2				1.2				-1.2			
	Second Day				Fifth Day				Eighth Day			
C	8.2	2.4	2.62	.92	1.8	3.1	1.21	2.56				
X	5.8				-1.3							
C	8.2	4.5	2.65	1.70	1.8	3.3	1.10	3.00				
H	3.7				-1.5							
X	5.8	2.1	.92	2.28	-1.5	.2	1.10	.18	1.4	3.7	1.37	2.70
H	3.7				-1.3				-2.3			
	Third Day				Sixth Day							
C	2.9	1.5	.89	1.69	.3	.4	1.23	.32				
X	1.4				-.1							
C	2.9	1.3	.96	1.35	.3	.4	.93	.43				
H	1.6				.7							
X	1.4	.2	.90	.22	-.1	.8	1.26	.63				
H	1.6				.7							

TABLE XXXV

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN MEAN PERCENT ORIGINAL WEIGHT RETAINED EACH DAY OF MAZE RUNNING IN ORIGINAL LEARNING

Group	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.
	First Day				Fourth Day				Seventh Day			
C	92.7	.4	.61	.65	84.6	3.1	1.19	2.61	83.2	6.6	2.17	3.04
X	93.1				87.7				89.8			
C	92.7	.5	.66	.76	84.6	4.3	1.15	3.74	83.2	7.8	2.38	3.28
H	92.2				88.9				91.0			
X	93.1	.9	.65	1.38	87.7	1.2	1.10	1.09	89.8	1.2	2.11	.57
H	92.2				88.9				91.0			
	Second Day				Fifth Day				Eighth Day			
C	88.0	1.4	.81	1.73	84.9	4.1	1.37	2.99				
X	89.4				89.0							
C	88.0	2.0	.77	2.60	84.9	4.9	1.50	3.27				
H	90.0				89.8							
X	89.4	.6	.70	.86	89.0	.8	1.25	.64	90.3	1.2	2.40	.50
H	90.0				89.8				91.5			
	Third Day				Sixth Day							
C	86.0	2.5	.93	2.67	85.0	5.2	1.74	2.99				
X	88.5				90.2							
C	86.0	3.4	.98	3.47	85.0	4.7	1.74	2.70				
H	89.4				89.7							
X	88.5	.9	.78	1.17	90.2	.5	1.60	.31				
H	89.4				89.7							

TABLE XXXVI

MEANS, STANDARD DEVIATIONS AND STANDARD ERRORS FOR LOSS OF WEIGHT DURING RELEARNING--1st & 2nd DAYS

	First Day				Second Day			
	N	Mean	σ	$\sigma/\sqrt{N}$	N	Mean	σ	$\sigma/\sqrt{N}$
Rats relearning in cold room								
a. from C	17	16.8	6.45	1.57	9	5.4	5.35	1.78
b. from X	14	14.9	3.71	.99	10	4.2	4.48	1.42
c. from H	16	13.7	5.02	1.26	13	5.7	3.31	.92
all in C	47	15.2	5.43	.79	32	5.1	4.39	.78
Rats relearning in control room								
a. from C	17	15.9	7.88	1.90	14	3.5	3.18	.85
b. from X	15	11.2	5.62	1.45	11	2.2	2.78	.84
c. from H	16	12.4	4.05	1.01	15	4.2	3.81	.98
all in X	48	13.2	6.50	.94	40	3.3	3.43	.54
Rats relearning in hot room								
a. from C	14	12.1	4.06	1.09	14	2.2	2.65	.71
b. from X	15	11.8	3.63	.94	15	2.3	2.69	.70
c. from H	14	9.5	3.01	.80	13	1.7	3.30	.92
all in H	43	11.1	3.77	.57	42	2.1	2.94	.46

sub-groups, during the first and second days of relearning for the rats in each room. In view of the size of the standard errors for the second day, there is some question as to the reliability of these means. For the first day, however, the means appear to be reliable. Considering all the rats relearning in each room as a group, it can be seen that the rats moved into the cold room lose the most weight each day, and that these animals also relearn the maze most rapidly. All of the rats in the control room stand second in both measures, with the hot room relearners third in both mean weight loss and trials.

Table XXXVII indicates the reliability of the differences in mean weight loss the first and second days of relearning when differences between sub-groups are considered as well as when all groups in each room are combined. There is some evidence that there are significant differences in loss of weight when all the rats in each room are combined. Critical ratios for differences between sub-groups are all small and are probably not significant on a purely statistical basis.

The possibility of consistent trends in weight loss of sub-groups within rooms should not be overlooked. While the differences may be too small to be significant statistically, the same order in each room may well indicate some relation. The rank of relearning in each room can be compared with the order the three groups in each room occupy with respect to

TABLE XXXVII

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN MEAN LOSS OF WEIGHT EACH DAY OF MAZE RUNNING--RELEARNING

	First Day				Second Day			
	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.
A. Rats relearning in same room								
Cc Xc	16.8 14.9	1.9	1.85	1.03	5.4 4.2	1.2	2.28	.53
Cc Hc	16.8 13.7	3.1	2.01	1.54	5.4 5.7	.3	2.00	.15
Xc Hc	14.9 13.7	1.2	1.60	.75	4.2 5.7	1.5	1.69	.89
Cx Xx	15.9 11.2	4.7	2.39	1.97	3.5 2.2	1.3	1.19	1.09
Cx Hx	15.9 12.4	3.5	2.15	1.63	3.5 4.2	.7	1.30	.54
Xx Hx	11.2 12.4	1.2	1.77	.68	2.2 4.2	2.0	1.29	1.55
Ch Xh	12.1 11.8	.3	1.44	.21	2.2 2.3	.1	.99	.10
Ch Hh	12.1 9.5	2.6	1.35	1.93	2.2 1.7	.5	1.16	.43
Xh Hh	11.8 9.5	2.3	1.23	1.87	2.3 1.7	.6	1.16	.52
B. All rats relearning in each room								
all in C " " X	15.2 13.2	2.0	1.22	1.64	5.1 3.3	1.8	.95	1.89
all in C " " H	15.2 11.1	4.1	.97	4.22	5.1 2.1	3.0	.90	3.33
all in X " " H	13.2 11.1	2.1	1.10	1.91	3.3 2.1	1.2	.71	1.70

weight losses each day. The symbol standing first in the trials indicates the most rapid learning, and that placed first in the weight losses indicates the greatest mean loss of weight.

TABLE XXXVIII

RANK OF SUB-GROUPS IN EACH ROOM IN RELEARNING TRIALS AND MEAN WEIGHT LOSSES EACH DAY

Relearning (Trials)		Mean Weight Loss		
		1st day	2nd day	3rd day
Cold Room	C X H	C X H	H C X	C H X
Control Room	C H X	C H X	H C X	C X H
Hot Room	C H X	C X H	X C H	H X C

In the cold room, the rank in trials and weight losses is the same the first day, but on the second and third days about the only similarity is that the control group is found in last place in weight losses. There is better agreement between the two factors in the control room, with the control room rats in last place both in trials and in weight loss for the first two days. In the hot room, the rats originally from that room lose the least weight the first two days, but are second in learning. The cold room rats occupy each position once in weight, while the control room rats, last in learning, fail to fall in last place in the weight measures on any of the days. In this particular measure there seems to be but slight relation between learning and the weight lost each day of maze running.

As was mentioned before, the percent original weight retained rather than absolute weight loss is perhaps a better measure for determining this relation between weight and relearning. Figure 20 (page107) gives a picture of the changes for all the rats relearning in each room. Here we find the rats in the cold room retain less of the original weight and it is these rats which relearn the maze most rapidly. The control and hot room groups are second and third, respectively, in both measures. The percentages for the sub-groups within each room are given in Table XXXIX.

TABLE XXXIX

MEAN PERCENT ORIGINAL WEIGHT RETAINED BY EACH SUB-GROUP--FIRST AND SECOND DAYS OF RELEARNING

	1st day Mean	2nd day Mean	3rd day Mean
Rats relearning in cold room			
a. from cold room	92.8	90.1	
b. from control room	92.7	90.7	
c. from hot room	92.9	90.3	
d. all rats in cold room	92.8	90.4	88.1
Rats relearning in control room			
a. from cold room	93.0	92.1	
b. from control room	94.6	93.9	
c. from hot room	93.8	91.6	
d. all rats in control room	93.8	92.4	91.6
Rats relearning in hot room			
a. from cold room	93.8	93.1	
b. from control room	94.2	93.2	
c. from hot room	94.6	93.7	
d. all rats in hot room	94.2	93.3	92.9

The rankings of the sub-groups in each room for the relearning tests and the percent of the original weight retained are compared in the table below. The sub-group listed first in each room has lost the greatest percent of the original weight.

TABLE XL

RANK OF SUB-GROUPS IN EACH ROOM IN RELEARNING TRIALS AND MEAN PERCENT ORIGINAL WEIGHT RETAINED

		Mean % original weight retained	
Relearning	(Trials)	1st day	2nd day
Cold Room	C X H	X C H	X H C
Control Room	C H X	C H X	H C X
Hot Room	C H X	C H X	C X H

The control rats in the cold room lose relatively more weight than the other groups on both days, yet these rats are second in relearning the maze. The cold room rats staying in that room are first in learning, yet they occupy second and third places on the two days in terms of percentage weight loss. The control room rats in the control room show the slowest relearning and retain the greatest percent of their original weight. Rats from the cold and hot rooms have the same order for the first day of weight measures and relearning tests. On the second day the two are transposed in order. Again in the hot room the first day weights are in the same order as in maze running. On the second day the hot and control groups are out of order, but here again the cold room rats stand first.

If only the first day weight records are considered, there is considerable correspondence between the two measures. The second day results are somewhat more confused. In general, there seems to be better relation between relearning tests and weight losses when the latter are considered in terms of percentage original weight retained, than when absolute weights were considered. The discrepancies are still large enough, however, to leave doubt as to any consistent relation between the two measures.

There remains still another method of isolating the possible relation between weight loss and relearning scores. If some single measure of weight loss can be used, the coefficient of correlation between that factor and relearning scores can be determined. One possible means of expressing such weight losses is to find the average weight loss per day of maze running. In this measure the full number of days needed for relearning can be utilized. Although there is considerable evidence that the loss of weight is not directly related to "hunger" and that there may be considerable loss of weight without direct increase in hunger, the periods considered are short enough to suggest that the two factors must have some connection.

The coefficientsof correlation between the mean weight loss per day of maze running and trials on relearning tests for all rats in each room were calculated. Using the Pearson product moment method, the following values for r were found:

all rats in the cold room $r = +.24 \pm .097$

all rats in control room $r = +.66 \pm .053$

all rats in the hot room $r = +.37 \pm .088$

Table XLI gives the correlations found for the rats in the sub-groups within each room. As there were but 15 to 17 rats in each group, the rank difference method was used.

With only one exception, all of the coefficients are positive, ranging from -.06 to +.71. The median for the nine sub-groups is +.39. Although the values themselves are rather low, when these are considered in the light of the other tendencies noted, it seems possible that these coefficients are indicative of some relation between the two variables. It may be that the large number of variables which were uncontrollable in this experiment act to reduce the size of the coefficients, without destroying the possibility of some correlation.

One other set of measures can be examined before any conclusions as to the relation between weight losses and performance exhibited by the rats are formulated, namely, weight losses during each day of the grid tests. In the obstruction

TABLE XLI

CORRELATION BETWEEN RANK IN MEAN WEIGHT LOSS PER DAY OF MAZE RUNNING AND RELEARNING SCORES (TRIALS)

In the cold room	
a. rats from the cold room	+.26
b. rats from the control room	+.37
c. rats from the hot room	+.66
In the control room	
a. rats from the cold room	+.71
b. rats from the control room	+.67
c. rats from the hot room	+.22
In the hot room	
a. rats from the cold room	-.06
b. rats from the control room	+.48
c. rats from the hot room	+.39

TABLE XLII

MEAN WEIGHT LOSSES DURING GRID TESTS

		First Day				Second Day				Third Day		
	N	Mean	σ	$\sigma/\sqrt{n}$	N	Mean	σ	$\sigma/\sqrt{n}$	N	Mean	σ	$\sigma/\sqrt{n}$
Rats tested in cold room												
a. from C	16	18.5	5.90	1.50	17	8.3	3.99	.97	17	11.0	3.17	.78
b. from X	10	18.4	5.02	1.57	10	5.8	3.95	1.23	10	10.7	5.18	1.62
c. from H	8	19.2	6.94	2.30	10	5.2	3.62	1.13	10	10.3	3.91	1.22
all in C	34	18.6	8.16	1.40	37	6.8	4.14	.68	37	10.7	4.00	.66
Rats tested in control room												
a. from C	12	16.7	4.06	1.17	12	3.6	2.39	.69	12	10.1	2.55	.74
b. from X	15	14.7	4.51	1.16	17	4.8	3.19	.77	17	9.7	9.90	2.40
c. from H	9	17.1	7.81	2.64	11	3.5	3.13	.94	11	9.0	5.88	1.77
all in X	36	16.0	4.98	.83	40	4.1	9.46	1.50	40	9.6	7.32	1.16
Rats tested in hot room												
a. from C	10	15.8	6.07	1.92	10	3.4	3.29	1.04	9	6.1	4.21	1.40
b. from X	10	13.4	5.12	1.62	10	3.0	6.52	2.06	9	6.3	2.45	.78
c. from H	16	14.2	6.76	1.69	17	5.7	3.84	.93	16	6.8	3.55	.89
all in H	36	14.4	6.22	1.04	37	4.4	4.78	.79	35	6.5	3.49	.59

TABLE XLIII

RELIABILITY (CRITICAL RATIOS) OF DIFFERENCES IN WEIGHT LOSSES DURING GRID TESTS

Group	First Day				Second Day				Third Day			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
Cc	18.5	.1	2.17	.05	8.3	2.5	1.56	1.60	11.0	.3	1.80	.17
Xc	18.4				5.8				10.7			
Cc	18.5	.7	2.73	.26	8.3	3.1	1.49	2.08	11.0	.7	1.45	.48
Hc	19.2				5.2				10.3			
Xc	18.4	.8	2.76	.29	5.8	.6	1.67	.36	10.7	.4	2.03	.20
Hc	19.2				5.2				10.3			
Cx	16.7	2.0	1.65	1.20	3.6	1.2	1.03	1.17	10.1	.4	2.56	.16
Xx	14.7				4.8				9.7			
Cx	16.7	.4	2.89	.14	3.6	.1	1.17	.09	10.1	1.1	1.92	.57
Hx	17.1				3.5				9.0			
Xx	14.7	2.4	2.89	.83	4.8	.7	1.21	.58	9.7	.7	2.98	.23
Hx	17.1				3.5				9.0			
Ch	15.8	2.4	2.51	.96	3.4	.4	2.30	.17	6.1	.2	1.60	.13
Xh	13.4				3.0				6.3			
Ch	15.8	1.6	2.56	.63	3.4	2.3	1.39	1.65	6.1	.7	1.66	.42
Hh	14.2				5.7				6.8			

TABLE XLIII (CONTINUED)

Group	First Day				Second Day				Third Day			
	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.	Mean	Diff	σDiff	C.R.
Xh	13.4	.8	2.34	.34	3.0	2.7	2.26	1.19	6.3	.5	1.18	.42
Hh	14.2				5.7				6.8			
All in C	18.6	2.6	1.63	1.60	6.8	2.7	1.65	1.64	10.7	1.1	1.34	.82
All in X	16.0				4.1				9.6			
All in C	18.6	4.2	1.74	2.41	6.8	2.4	1.04	2.31	10.7	4.2	.89	4.72
All in H	14.4				4.4				6.5			
All in X	16.0	1.6	1.33	1.20	4.1	.3	1.69	.18	9.6	3.1	1.30	2.38
All in H	14.4				4.4				6.5			

box, we might expect that those rats losing the most weight would cross the grid the greatest number of times, as the need for food would be correspondingly greater. This is, of course assuming that there are no physiological changes during weight loss which act to change the intensity of the electrical shocks. Weight losses in grams each day of the grid tests are shown in Table XLII. The sigmas and standard errors indicate that in general these means are reliable. The critical ratios for the reliability of the differences of the means are given in Table XLIII. The values are all quite low for the differences between the sub-groups in any room. However, when all rats in each room are considered as a single group, the values for the critical ratios increase considerably. They are fairly high for the differences between the hot and cold rooms. This was found true, it will be remembered, when relearning and weight losses in the maze were considered, and may indicate that, at least in the two extreme rooms, the differences found can be considered fairly reliable from a statistical standpoint.

TABLE XLIV

RANK OF SUB-GROUPS IN EACH ROOM IN
GRID CROSSINGS AND WEIGHT LOSSES EACH DAY

	Grid crossings	Mean weight loss each day		
		1st day	2nd day	3rd day
Cold room	H X C	H C X	H C X	C H X
Control room	H C X	C X H	X C H	H C X
Hot room	H X C	C X H	C X H	H X C

Within rooms, the relation between grid crossings and weight losses can be determined by noting the order of each sub-group in the three rooms. (Table XLIV)

In the cold room, the sub-group from the control room lost the least weight, yet this group is in the center position in crossings. The hot room rats are first in crossings and weight loss for the first two days, yet are in middle place in weight loss on the third day when tests were given. The cold room rats are last in crossings, yet are in second place in the weight losses for the first two days and in first place the day of the tests. In the control room the order agrees if only the weight losses the third day are considered, but on the other two days the hot room sub-group, which makes the most crossings in that room, is last in weight loss. The same relation holds in the hot room. Here the order is the same if only the third day is considered. On the first and second days, the cold room rats show the greatest weight loss but are last in number of crossings. Hot room rats are last in weight loss but first in number of crossings.

The weight losses expressed in terms of the percent original weight retained each day are given in Table XLV.

TABLE XLV

MEAN PERCENT ORIGINAL WEIGHT RETAINED EACH DAY OF GRILL TESTS

	N	1st day Mean	2nd day Mean	3rd day Mean
Rats tested in cold room				
a. from cold room	16	92.2	88.6	83.8
b. from control room	10	91.6	88.9	83.8
c. from hot room	8	90.1	87.1	81.8
d. all tested in cold	34	91.5	88.3	83.3
Rats tested in control room				
a. from cold room	12	93.3	91.7	87.2
b. from control room	15	93.4	91.3	86.7
c. from hot room	9	92.2	90.3	86.1
d. all tested in cont.	36	93.1	91.2	86.7
Rats tested in hot room				
a. from cold room	10	92.1	90.4	89.2
b. from control room	10	92.4	91.7	88.1
c. from hot room	16	93.4	90.4	87.1
d. all tested in hot	36	93.0	90.8	88.0

The differences between rooms are about the same as in the relearning tests and weight losses. The rats in the cold room, regardless of origin, retain less of their original weight, and cross the grid more frequently. In the control and hot rooms fewer crossings are found, but more of the original weight is retained. The order of the two measures can be examined for rats within each room. These orders are given below.

TABLE XLVI

RANK OF SUB-GROUPS IN EACH ROOM IN
GRID CROSSINGS AND PERCENT ORIGINAL WEIGHT RETAINED

	Grid crossings	Percent original weight retained		
		1st day	2nd day	3rd day
Cold room	H X C	H X C	H C X	H (XC)
Control room	H C X	H C X	H X C	H X C
Hot room	H X C	C X H	(HC) X	H X C

When the weight losses are considered in this manner, there is a much better correspondence between the two measures. Rats originating in the hot room crossed the grid most frequently whether they were tested in the hot, control or cold rooms. All of these rats when moved to the control and cold room show the greatest weight loss all three days. The group originating and remaining in the hot room comes last in weight loss the first day, tied for first place on the second day with the rats originating in the cold room and moved to the hot, and on the day of the tests, the third day, stands in first place. The cold and control sub-groups, whether those moved or not, occupy either second or third places during the three days of the tests. There is no definite trend here, except that these rats seldom occupy first place in weight losses.

If the mean loss of weight per day of grid tests is taken as a single measure of the weight losses, the coefficient of correlation between the weight changes and the crossings can be determined. These values are given in Table XLVII.

TABLE XLVII

CORRELATION BETWEEN LOSS OF WEIGHT PER DAY OF GRID TESTS AND GRID CROSSINGS

In the cold room	
a. rats from the cold room	+.30
b. rats from the control room	−.15
c. rats from the hot room	+.57
In the control room	
a. rats from the cold room	+.07
b. rats from the control room	+.19
c. rats from the hot room	+.58
In the hot room	
a. rats from the cold room	-.03
b. rats from the control room	+.17
c. rats from the hot room	+.16

The coefficients are somewhat lower than the corresponding values found when the relearning trials and weight losses per day were compared. There are only two that are not positive, however, and two or three are fairly high. As was pointed out earlier, there may be uncontrolled factors present which act to reduce the values of the coefficients without necessarily destroying any relation between the weight losses and grid crossings.

A summary of the performance on both the maze and the grid compared with the weight losses in both measures may be helpful at this time. If all the rats in each room are grouped together, we find the following orders in the different measures.

TABLE XLVIII

SUMMARY BY ROOM OF PERFORMANCE AND WEIGHT LOSSES

Relearning (trials	C X H	
Mean wt. loss per day	C X H	
Mean percent original weight retained	C X H	(smallest value 1st)
Total grid crossings	C X H	
Mean wt. loss per day	C X H	
Mean percent original weight retained during grid tests	C X H	(smallest value 1st)

The pattern of results is the same when all rats in each room are grouped together. Relearning, grid crossings, weight losses per day and percent original weight retained all occur in the same order. In every case the rats in the cold room stand first, the control room animals second and the rats in the hot room third. On this basis alone, it would seem that there is a close relation between maze performance, grid crossings and amount of weight lost during each measure.

The performance of the sub-groups within the rooms can now be examined. The relations between these groups when performance and weight losses are considered are given in Table XLIX.

The general results found in the relearning and in the two measures of weight loss during this part of the experiment correspond fairly closely. The cold room sub-group (originated in cold room) stands in first place in the

Table XLIX

SUMMARY BY SUB-GROUPS OF PERFORMANCE AND WEIGHT LOSSES WITHIN EACH ROOM

	Cold	Control	Hot
Relearning (trials)	C X H	C H X	C H X
Mean weight loss per day	C H X	C H X	X H C
Mean percent original weight retained during relearning	C H X	H C X	C H X
....			
Total grid crossings	H X C	H C X	H X C
Mean weight loss per day	C (HX)	H C X	H C X
Mean percent original weight retained during grid crossings	X C H	H X C	H C X

three measures taken during relearning in the cold room, the hot room sub-group in the cold room was second in two of the measures, the control sub-group was last in two of the measures. About the same degree of correspondence is found in the other two rooms. The cold sub-group tested in the control room is first in two of three measures taken during relearning tests. The rats from the hot room are second two of the three times while the control room sub-group tested in the control room is last every time. While in the hot room the cold room rats are first in two of the three measures; the hot room rats while in the hot room are second every time, and the control room sub-group is last two of the three times.

As has been pointed out, there is little agreement in the order of the sub-group in each room when relearning and grid crossings are compared. However, the weight losses during grid tests and the total grid crossings for the sub-groups in all three rooms show a fair degree of relationship. Also, there is considerable relation between the weight losses and relearning ability of the sub-groups in all three rooms. Evidently the same sub-groups of rats, when measured for relearning and grid crossings, ranked differently in weight losses.

Qualitative Observations

Certain qualitative observations may aid in giving a more complete picture of the behavior differences found in the three rooms. Differences mentioned by Hellmer were carefully watched for, in order to check their occurrence.

The general level of activity varied considerably in the three rooms. Rats in the hot room showed little inclination to move about spontaneously in the cages. In the maze situation periods of rather rapid running were interrupted by long periods of sleeping, sniffing, grooming, or huddling in a corner. The behavior in the maze was rather erratic, and occasionally many errors would be made in a trial following an errorless run. It was noticed many times that during the first few trials most rats in the hot room, regardless of origin, would explore almost all of the maze during the first trial on a given day. If, however, they missed the food box, they would then retrace their path, and spend the rest of the period in going up and down the first or second alley. The behavior in this room almost seemed stereotyped at times, in that certain errors, once made, were repeated without exception for many trials thereafter.

Although the weight records indicate that the hot room rats lost the least weight during the maze tests, they seemed nevertheless to compete vigorously for the food when it was presented after the maze trials for the day. Quite frequently vigorous struggles for possession of the food can would develop, and result in overturning the food.

In the grid tests many of the rats in the hot room made no crossings and but few contacts. The general pattern of activity was one of cautious contacts with the grid every now and then, but those rats spent most of the time crouching or sleeping in some corner and showing little interest in the food. Occasionally the animal engaged in desultory scratching and biting at the screen wire covering the starting chamber. Many would stand on their hind legs and claw at the covering for several minutes at a time, even going so far as to try to hang suspended by all four legs from the screen.

During the first few weeks in the cold room the rats, originating there, were quite active and spent less time in their nests than when they became older. In the maze trials the behavior was fairly uniform. In most cases progress was fairly steady. When an unusually large number of trials was required, there were more instances of clear out refusals to run during the first part of the test than of erratic behavior of the type found in the hot room. The cold room rats ate steadily and quietly during the feeding periods after maze trials. There were few struggles for possession of the food can. However, there were frequent attempts to "hoard" excess food by taking it from the can and placing it in a corner. This type of behavior never occurred in the hot room during observations made by the experimenter.

Only a few rats tested in the cold room refused to cross the grid at some time during the 20 minute period. Those that did refuse spent considerable time in approaching the grid or cautiously touching it. If this type of behavior died down, there was a tendency to sit quietly in a corner. Occasionally attention was diverted to the screen covering, but not as often as in the hot room.

In general rats tested in the control room showed some of the characteristic behavior of both hot and cold rats. The general level of activity throughout the experiment was perhaps greater than in the other rooms. Maze behavior did not seem to be as erratic as in the hot room. During the feeding periods there were occasional struggles for the food can, although no instances of "hoarding" were found. When tested in the obstruction box about the same type of behavior was displayed as in the cold room. Of course fewer crossings were observed, and more time was spent either in crouching in a corner or clawing at the screen covering of the starting chamber.

Most of the outstanding characteristics of behavior which Hellmer mentioned were found to occur in the present study. In particular, it was found that the maze performance was quite similar. Changed experimental conditions of course prevented a complete check on all aspects of behavior which he mentioned.

Discussion of Results

In the present study an analysis of the behavior of white rats living in different room temperatures has been carried out along two main lines. First, maze performance under <u>changing</u> temperatures was investigated. From an examination of the results, it seems fairly certain that the performance exhibited is closely related to the temperature under which the animals lived. However, this relation in itself does not give a detailed or differentiated picture of the possible ways in which the different temperature conditions act directly or indirectly upon the animal to produce the differences found in the maze performance. Accordingly a second approach was attempted. Possible ways in which the temperature differences affected the rats through a study of their weight differences, and responses to a barrier, between them and food, in the form of an electric grill were investigated.

In order to make a comparative study of learning ability, as we have done here, the ideal condition is that every variable except one be held constant. If certain variables are permitted to change, the direction and extent of the change should be determined, and controlled. In the present study control of the external conditions of food, light, maze procedure, food deprivation, etc., probably does not mean that all variables save temperature have been kept constant.

In the process of adjustment to the different temperature conditions, certain physiological and organic changes take place, which necessarily are different under different temperature conditions. Thus many factors vary along with the temperature changes. To determine what these changes are, and the extent of the shifts found is not to deny that the temperature may be the key factor which initiates the pattern of changes. Investigation of these patterns simply increases our understanding of the method through which the temperature changes bring about the differences in behavior and gives a more differentiated picture of the changes by means of which similar animals respond to the different temperature conditions.

First of all, there are many indications that the rats living in the cold room exhibit a higher rate of metabolism than do those living in the 90°F room. The rapid rate of growth, and general earlier development would point to this fact. Hellmer (24) reported that the average date of conception for the rats in the cold room was approximately two weeks ahead of that of the hot room. Mills(46) also points out many lines of evidence for this increase in metabolism in people living in the tropics. An abstract of Djelineo's study (18) indicates that with white rats, the higher the temperature, the lower the basal metabolism rate. The metabolic rate was determined on the basis of oxygen consumption, and marked differences were found for rats living since birth in rooms of different temperatures. In some extreme temperatures, the ratios of the metabolic rates was as great as 2:1. Changing the environment of an adult rat influences its rate of metabolism as well. Quoting from the abstract:

"Thus a rat which was adapted to 5-10° C showed a BMR of 859 Cal; after 5 weeks under 16-20° C the BMR fell to 676 C., after one month under 30-32° C to 517 Cal."

Djelineo found that a change from higher to lower temperatures increases the BMR for a time. If the rate of learning is related to metabolism, this temporary increase might account for the relatively better performance of the hot room groups over the control groups, when both are tested in the cold room. It is also interesting to note that the temperatures Djelineo is reported to have used fall somewhere near those employed in the present study; when the Centigrade temperatures are changed to Fahrenheit we have 40-50° F, 60-68° F and 86-90° F.

Heron and Yugend (27) report the development of a "bright" and "dull" strain of rats, and suggest that the difference in metabolism in favor of the "bright" group may account for some of the differences found in learning. If we assume that the cold room animals in the present experiment exhibit a higher BMR, a similar relation between learning ability and rate of metabolism is found in the present study.

The differences in the amount of food consumed in the three rooms, along with the weight losses during food deprivation, can also be thought of as additional evidence for the difference in metabolism in the three rooms. Although no quantitative measure of the amount of food consumed was kept, the general observation was that the cold room animals did require the most food. During the 24 hour period of food deprivation, the cold room rats tended to lose more weight than did those in the hot room. This is to be expected if the rats in the hot room have a lower rate of metabolism. Weight records kept during learning, relearning, and grid tests all check as to the smaller loss of weight during the same period of food deprivation by the hot room rats.

This fact suggests that a difference in the degree of motivation may be operating as one of the factors that change along with the temperature. On a room by room basis there is considerable evidence that this relation holds. It must be remembered, however, that the basis of this conclusion is the assumption that hunger and "drive" are closely related. Most investigators agree that in general hungry rats are more active than non-hungry rats, and usually learn simple mazes more rapidly. (See Tolman and Honzick (67)). Also, many agree that increased periods of food deprivation tend to produce an increase in motivation, as measured by efficiency of maze learning, until the animal becomes weakened by starvation. Heron and Skinner (26) indicate that hunger increases with starvation until about the fifth day of deprivation, followed by a rapid drop in hunger until death occurs. An abstract of Vojtonis' study (69) reports that he found an increase in motivation as a result of food deprivation from eight to twenty-four hours, followed by a constant level during the next thirty-two to forty-eight hours.

Other evidence, however, throws doubt on a close relation between food deprivation and motivation. It has been found that after long training, satiated rats continue to run the maze. Vojtonis suggests that perhaps a new motive, simply a tendency to run through the maze, has been set up. In some instances lessening the "drive" by feeding groups of hungry rats before maze tests leads to better performance than non-fed hungry rats. Bruce (13) reports such a study, and suggests that motivation can be considered in several ways, some of which are not directly related to the drive for food.

The use of the obstruction box also has certain disadvantages as a measure of motivation during food deprivation. The physiological changes that take place during deprivation are not clear. As pointed out by Ligon (39) the degree of punishment may vary for various physiological states. Since the condition of the animal may change during the periods of deprivation, the differences in crossings may not be measures of motivation but rather of physiological changes. He suggests, as others have already pointed out, that the drive may not increase quantitatively as the deprivation increases. Also, emotional excitement is probably different with different degrees of deprivation. Lignon concludes that the length of starvation period, even when it does not result in suffering, does not determine the degree of motivation.

Other investigators conclude usually, that within limits, activity and drive as shown by crossing the grid in the obstruction box tend to increase until the animal is weakened by food deprivation. Moss (49) places no definite limits as to when activity declines. Holden (21) believes this decrease may come after twenty-four hours of starvation, while Warner (71) states that the tendency to cross the grid is at a maximum after three to four days of food deprivation, and decreases thereafter. Females act somewhat differently in that they reach the point of greatest activity at about two to three days. An abstract of Rasmussen's report (59) indicates that the period of maximum attempts to eat ranges from one-half to six days of food deprivation.

In our obstruction box experiments food deprivation was not great enough to weaken the animals, and probably falls in the period where the motivation increases with the starvation period. Hence we may assume that the results roughly represent the motivational factors involved.

Under the conditions of the present experiment, still another complicating set of circumstances arises. The different physiological adjustments demanded by the three temperature conditions may act to produce diet deficiencies in one group and not in another, when all rats are fed the same food. These deficiencies may in turn act to change the motivational factors beyond that which may be imposed by the difference in metabolism and starvation periods alone. Here may be another factor which changes along with temperature changes. It may be possible that temperature differences and maze performance are related through the action of such deficiencies.

Mills (47) reports that food mixtures with enough vitamin B_1 to permit long healthy life of rats in a cold room (68° F) left rats kept in a 90° F room runty and stunted. Those animals in the hot room needed for normal growth twice as much of the B vitamin thiamin (B_1) as did those in the cold room. It also took five times as much choline for the 90° rats as for the 68° animals. He also reports that the other B vitamins are required in larger amounts in the hot room. Mills points out that the B complex is needed to assure proper food oxidation, and with the more sluggish conditions of tropical heat, larger amounts are needed.

Recently the relation between maze learning and certain vitamin deficiencies has been investigated. In a series of articles Maurer (41), (42), (43), points out that groups of rats deprived of an adequate quantity of vitamin B_1 require about twice as many trials and errors to learn a maze as do the control groups. The same observation holds for B_2 deficient groups. On the other hand vitamin A deficient groups learned the maze as rapidly as the normals. E. Poe, C. F. Poe, and K. F. Meunzinger in several articles (50), (57), (58), report somewhat different results, in that they believe the B_2 vitamin deficiency makes no difference in maze performance. They do agree with Maurer in that B_1 deficient groups were below normals in maze running.

Protein, phosphorus and iron deficiencies in diet tend to produce poorer maze performance than for normals, Bernhardt reported (6), (7). These differences were small and consistent, but statistically unreliable. With Herbart (8), he also indicates that groups, vitamin B deficient from an early age, were poorer in learning than groups deficient for a shorter time, although again the differences were not reliable statistically. The reason for this difference probably lies in the greater need for the B vitamin during the rapid growth of the nervous system during early life.

In view of the results reported in the present experiment, it does not seem likely that these deficiencies alone can account for the differences in behavior that were found. If we accept Mills' report that hot room rats need more of the B_1 vitamin, and Herbert and Bernhardt's suggestion that early vitamin deficient groups learn more slowly than late deficient groups, we still cannot explain the performance of the hot room groups relearning in the different rooms. Here are groups deficient in the essential vitamin from an age of about four weeks which show better performance in most of the measures than a supposedly normal group from the control room. In many cases, however, there was less difference between the cold and hot room sub-groups relearning in any one room than between either one, and rats originally from the control room.

There is also a question whether the deficiencies in diet, whatever they may be, could produce such wide variations in performance as were found in the relearning in the rats in the hot and cold rooms. It must take some time to produce diet or vitamin deficiencies in rats which have had adequate diets. Thirty to forty days do not seem to be long enough to produce a physiological condition in the rats moved to unfavorable conditions that would be similar to that of rats spending their entire life in unfavorable conditions.

It would seem reasonable to suppose that different temperatures probably exert a more or less direct influence upon those aspects of the rats' metabolism that lead to better learning on the one hand and poorer learning on the other, whether the differences in learning result from differences in intelligence, in motivation, or both.

CHAPTER IV

INTERPRETATIONS

The Present Study

In this study we have attempted to isolate a few of the relationships found between the organism and its environment when one aspect of the environment is manipulated. Changes in temperature under which white rats lived were introduced and accompanying changes in maze behavior were recorded. At the present level of refinement, only relative gross changes can be demonstrated. There is no intention of insisting that temperature changes constitute the only important aspect of the environment which must be considered. Many lines of evidence, however, suggest that temperature may be more important than has been realized, and the clarification of such relationships may increase our understanding of other aspects of the functioning of the organism.

The growth of the rats in the three rooms of different temperature indicates a tendency to develop different gross body structures in the different temperatures. As a part of the adaptation to environmental changes, a new body pattern makes its appearance. Not only does the organism act selectively in responding to the environment, but when favorable aspects no longer exist, changes in the organism appear that lead to better adjustment. The mechanism of such changes is at present relatively unknown, and in the present experiment were not isolated. Child has suggested that changes in certain physiological gradients may be responsible for changes in structure. The physiological gradients consist of a graded difference in physiological activity, and include the velocities of chemical and physical reactions, collodial dispersion and ionization in different parts of the organism. The environmental energies induce such gradients to form, and the structure and function of certain lower organisms are thus determined. By changing these gradients, changes in the structure of the lower organisms can be brought about, but in the higher organisms the gradients are more difficult to change. As May (45) said, "Heredity supplies the potentialities of excitation and reaction; it also determines the degree of persistence or effectiveness of the gradient. Environment, on the other hand, determines which gradient shall operate and how they shall operate." (p. 744)

The present study offers a suggestion that perhaps certain of these gradients have been altered by the different temperature conditions in the three rooms. The general pattern of the change in body structure was in the direction of increasing body surface in the hot room, and reducing body surface in the cold room. It will also be remembered that the tails of the hot room rats were signigicantly longer.

Mills (47) has pointed out that the ears and tails of rats act as radiators for the loss of excess body heat. In the hot room, where much body heat must be lost, changes in structure are found to facilitate this process. In the cold room the more rounded bodies and shorter tails expose less surface and thus aid in the conservation of body heat.

The lower temperature of the cold room, in forcing the rat to expend more energy in the process of adaptation, provides a more stimulating environment. It is doubtful, however, that a more rapid rate of metabolism is the only factor responsible in producing the greater level of activity, or more efficient performance in the maze. The entire pattern of adaptation which takes place when the rat lives under the lower temperature must involve a wide range of physiological adjustments. Just how these changes are related to the behavior patterns displayed is still uncertain. The differences in learning shown by the three groups of rats in the cold, control, and hot rooms leave little doubt that the temperature under which a rat lives and works is an important condition in influencing its maze behavior. The differences in maze learning in the three rooms are fairly large and were found to be statistically reliable. The present data support the results reported by Hellmer. In both experiments differences in the same direction and approximately the same extent were found.

Analysis of the data by means of the Vincent curves suggests that the rate of elimination of errors during different parts of maze learning has been altered. The lack of progress in elimination of errors in the last half of the learning of the maze in the hot room may indicate differences in the rate of the learning displayed in each room. It is possible that new adjustments as those required in maze learning cannot be maintained as continuously in the hot room as in the cold room. The weight-loss curves show that the hot room rats reach a period of little gain or loss at about the time the average number of errors begins to increase. The lack of progress in learning might thus be the result of a possible decrease in motivation. The control room rats, however, show about the same stabilization in weight losses without the marked lack of progress in maze learning.

The lack of progress during the fifth to seventh tenth of the trials required for mastery of the maze is again clearly shown by the Vincent curves for relearning. All of the rats relearning in the hot room, regardless of their origin, show a decided increase in errors during this part of the relearning. The rate of elimination of errors is greater in the hot room than in either the cold or control rooms until the fifth tenth. The data from daily weight records cannot account for this difference in progress. Again, the weight-loss curves do not correspond closely enough with the Vincent curves for rats relearning in the hot room to make it possible that differences in motivation are solely responsible for the rate of relearning found. More refined studies of the effect of temperature on differences in learning may clarify this problem.

Changes in performance in the same group of rats corresponding with changes in temperature were found in all three original groups of rats. The change in performance took place relatively rapidly and the adjustment seemed to be fairly complete. The critical ratios of the differences between groups relearning in the same room were all below a value of 2, and eleven of the twenty-seven were below a C.R. of 1. Thirty to forty days in the cold room was long enough to bring the performance of a group learning in the hot room but changed to the cold room, to almost the same level of performance as was found in a group which was left undisturbed in the cold room. When it is remembered that this same hot room group required almost twice as many trials as the cold room group for original learning, the magnitude of the change becomes striking. In like fashion, changing cold room groups to the hot room produced relearning scores almost the same as that of rats living the entire period in the depressing conditions of the hot room.

Whatever the pattern of changes initiated by the new temperature conditions may be, these changes began rapidly, and became effective in a very short time. The data also suggest that the adjustment made by the organism to its changed environment may be more delicate and flexible than previously believed. It is also quite possible that such adjustments are found in response to much smaller variations in temperature than the extremes used in the present experiment.

If the results of the obstruction box are taken as rough measures of motivation, then the temperature differences can also be thought of as producing differences in motivation in the three rooms. The absolute numbers of approaches, contacts, and crossings in the three rooms were different, but the general temporal pattern of activity was about the same in all three rooms. The critical ratios for the differences between sub-groups originally from different rooms but tested in the same room were all quite low. When all rats tested in each room were considered, the differences in crossings during each five minute interval as well as for the twenty minute total are statistically reliable. The evidence does not indicate, however, that all the observed differences in maze behavior can be reduced to differences in motivation. These differences are only part of the total pattern of variables that must be considered in clarifying the relation between temperature changes and differences in behavior.

Evidence of a relation between weight losses and maze performance was inconclusive. Although there are many studies which fail to reveal a direct correspondence between maze performance and food deprivation, under the present experimental conditions it seems justifiable to assume that the weight losses are related to degrees of motivation and would show up in differences in rate of learning. When maze performance, either learning or relearning, was considered on a room basis, weight losses and learning ability were found to be related. The critical ratios for the differences in weight loss were also large enough to indicate statistical reliability for these measures. When percent original weight retained in learning and relearning was considered, a fair degree of relation between this measure and maze performance was found. This was not only true when all rats tested in each room were used, but when the performance of the sub-groups in each room was considered. Finally, a low but consistently positive coefficient of correlation was found between mean weight loss per day of maze running and maze performance, either learning or relearning.

Little correspondence between weight losses and maze performance was found when the number of rats losing weight each day of original learning was considered. Also, there was little agreement between rate of first learning and the mean loss of weight by rats in each room during the last days of maze trials. The curves for percent original weight retained each day of original learning also fail to predict the efficiency in original learning. The weight of the evidence, however, points to some correspondence between weight losses and maze performance. More refined studies should be undertaken in order to clarify the degree of correspondence between the two measures.

The same general picture is found for the weight losses during grid tests. If all rats tested in the same room are compared with all tested in the other rooms, there is a consistent relation between grid crossings and weight losses. Again, the coefficients of correlation between mean loss of weight per day and grid crossings are for the most part positive.

Whether rats in each of the three rooms which were fed so as to equate weight losses would show a difference in maze performance, remains to be determined. Certainly more carefully controlled experiments of this nature should be carried out before final conclusions can be drawn. The present experiment, however, suggests that differences in metabolism resulting from different periods of food deprivation which in turn produce differences in weight losses, may be one of the methods through which the differences in temperature act upon the organism.

As we have already seen, the differences in grid crossings suggest differences in motivation of rats tested in the three rooms. The weight losses offer a means of reconciling the lack of agreement between grid crossings and relearning scores. For some reason that is not yet clear, individual rats showed different weight losses in the grid tests and in maze trials. If the weight losses are thought of as indicating or producing to some extent differences in motivation, then the different behavior in the grid tests and in the maze is related to the differences in motivation.

Although knowledge of the behavior of the rat cannot be translated directly to human behavior, any study dealing with the adjustment of an organism, whatever its degree of complexity, to its environment, raises certain speculations of interest to the student of human behavior. The relatively rapid adaptation of the rats to new temperature conditions, as shown by the maze behavior, suggests that, on a human level, there may be equally rapid and complete changes in certain aspects of behavior, when different temperatures are encountered. It is quite possible, and many lines of evidence support the conclusion, that long time variations of only a few degrees may initiate far reaching adjustments of the human organism in the establishment of a new equilibrium. As Wheeler has pointed out, these adjustments are reflected in a wide range of man's behavior, social and cultural as well as physiological. Although laboratory studies are limited as to the range of phenomena covered, it is possible to gain, through the use of controlled experiments, a better understanding of some of the adjustments which may be of basic importance in producing different behaviors.

Related Problems

The present study raises a number of problems which are directly related to the differences in behavior found in the three rooms. Future experiments along these lines may aid in increasing both the extent and depth of our understanding concerning problems that have been raised.

First of all, in such a series of experiments, the temperature which brings forth the maximum level of performance should be determined. This optimum temperature may not be the same for all types of behavior. Equally important is the question of the corresponding relative humidity related to the different temperatures. There should be more adequate and refined methods of control and variation of the humidity as well as temperature in the experiments. Temperature alone has an impact upon organism which differs as the accompanying humidity varies. Determination of the optimum conditions of temperature and humidity would seem to be a basic prerequisite for future work upon the problem of temperature and its effect upon behavior.

Second, the effect of different conditions upon succeeding generations should be found. Hellmer carried his study through two generations and reported that the differences he observed, both bodily changes and maze performance, seemed to be accumulative from one generation to the next. The point of stabilization in the adjustment of the organism to the different temperatures should be determined. It might be possible that successive generations in the cold room (at the temperatures used in the present study) would develop deficiencies just as the hot room rats seem to have done. If the rate of development were slower than in the hot room, two generations may not have been long enough to reveal such tendencies.

Third, the problem of the behavior of successive generations also brings up the question whether animals once adjusted to the extreme conditions for many generations would lose the flexibility or ease of adaptation that is apparent in the present study. That is, will rats of the tenth generation in the cold room make as rapid and complete an adjustment if placed in the hot room as the animals in the present experiment?

Fourth, related to the problem of adjustment to the difference is the question of how long a period would be necessary under the conditions of the present study. Is thirty to forty days the shortest time in which the adaptation can take place? Determination of the time required for fairly complete adaptation as measured by various tasks would give some indication as to how quickly the organism can adjust to new conditions.

Fifth, the effect upon behavior of some of the organic changes found in the different rooms should be investigated. In this manner, the relative importance of differences in metabolism, diet and weight losses can be isolated. Such a procedure will aid in giving a more complete and detailed picture of the pattern of changes initiated by the different temperatures and the role they play in producing the behavioral differences found. For example, tests might be carried out in the hot room with groups provided with extra amounts of certain essential vitamins to see if supplying this factor would eliminate the differences found in the present experiment between cold and hot rooms. The reverse of this, using vitamin deficient groups in the cold room, could be used as an additional check. The same type of procedure might be applied to the other organic changes which are the result of adaptation to the different temperatures.

Sixth, more adequate measures of the motivational factors should be made possible. Until this is done, a final interpretation of the learning difference between hot and cold rats cannot satisfactorily be made.

Seventh, a more complete picture of the total pattern of changes found in rats living under different temperature conditions is needed. Other types of learning problems should be investigated. Measures of general neurotic tendencies and possible differences in social behavior can also be made.

CHAPTER V

SUMMARY

Procedure

(1) Three groups of white rats were raised under the constant temperature conditions of 55° , 75° , and 90° F. respectively.

(2) Weekly weight records were taken and growth curves obtained.

(3) At 85-95 days of age, 45 rats in each room were tested for learning in a simple four alley maze. Records of trials, errors and time were kept. After learning, equal groups of 15 from each original room were distributed to three temperature conditions.

(4) Approximately 40 days after learning, each rat was tested for relearning.

(5) Vincent curves for both learning and relearning were obtained.

(6) Daily weight records for each rat were kept during maze tests, both learning and relearning.

(7) After relearning, each rat was tested in a modified obstruction box.

(8) Daily weight records during obstruction tests were taken.

(9) Tail length and body length measurements were made when the rats were killed at the end of the experiment (when all rats were from 18-21 weeks old). Body-length to body-weight and body-length to tail-length ratios were computed.

Results

(1) Rats in the cold room grew more rapidly than those in the control or hot rooms. Movement from one extreme temperature condition to the other tended to retard the rate of development compared with that of rats left in the original room.

(2) The rats remaining in the hot room throughout the course of the experiment developed longer, more slender bodies and relatively longer tails (average length 18.0 centimeters). Similar groups in the cold room were short and stocky, with shorter tails (average 16.5 centimeters).

(3) Rats living and learning the maze in the cold room have a great advantage over similar groups living in hot room. The control room group stands about midway between the hot and cold room groups in performance (average number of trials for learning, cold room 19.8; control room 25.9; hot room 36.6).

(4) In relearning tests, every time a group was moved to a room of higher temperature the number of trials required for mastery of the maze increased. Comparison was made with trials required for relearning of an equal group in the original room (cold rats relearned the maze in the cold room in 7.1 trials, in the control room 9.8, and in the hot room 13.0. Control room rats relearned in the control room 11.3 trials, in the cold room 7.9, and in the hot room 18.8. The hot room rats relearned the maze in the hot room in 16.5 trials, in the control room in 10.5, and in the cold room in 8.2 trials).

(5) Groups of rats originating in different rooms but relearning the maze in the same room, whether hot or cold, show almost the same level of ability. There is a slight tendency for rats from the control room relearning in any other room to show poorer performance than other groups relearning there.

(6) No significant sex differences in learning or relearning were found.

(7) Vincent curves constructed to aid in analysis of the learning curves indicate a decrease in performance during the latter portions of the learning in the hot room.

(8) In obstruction box tests, rats in the cold room

crossed the grid most frequently, with the rats in the control and hot rooms standing in second and third place.

(9) Almost no relation was found between relearning scores and grid scores.

(10) Records of weight losses during original learning show only a fair correspondence with learning scores.

(11) Records of weight losses during relearning show some correspondence with relearning scores if the comparison is on a room-by-room basis. This relationship drops considerably when the changes of the sub-groups within rooms are analyzed. Expressing the weight losses in terms of percent original weight retained increases the correspondence somewhat.

(12) A small but consistent relation was found between weight losses and grid crossings.

Conclusions

(1) The temperature under which rats live is an important condition of the efficiency of maze learning.

(2) Changes in performance of the same group are found which correspond with changes in temperature. The adaptation to the new conditions seems to be fairly rapid and complete under the experimental conditions.

(3) A survey of the relation of motivation as measured in the present study and food deprivation indicates a somewhat uncertain correlation between the two. A small but consistent relation between weight losses and learning, relearning, and grid tests was found. Differences in weight losses during relearning and grid tests possibly serve to eliminate the lack of correspondence between grid crossings and relearning.

(4) Suggestions made for further studies concerning the influences of organic changes upon motivation should be carried out if the problem of the relative importance of differences in motivation is to be clarified.

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