68-17,593

MAYYASI, Adil M., 1939-
THE EFFECTS OF NOISE, AIR IONS, AND ELECTRIC
FIELDS ON LIVING SYSTEMS.

The University of Oklahoma, Ph.D., 1968
Engineering, biomedical

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE EFFECTS OF NOISE, AIR IONS, AND ELECTRIC FIELDS ON LIVING SYSTEMS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

ADIL M. MAYYASI

Norman, Oklahoma

1968

THE EFFECTS OF NOISE, AIR IONS AND ELECTRIC FIELDS ON LIVING SYSTEMS

APPROVED BY

D. Harden

C. W. Bert

B. L. Foote

DISSERTATION COMMITTEE

ABSTRACT

Experimental animals (400 King-Holtzman hybrid breed of rats, 200 males half young and half adult and 200 females half young and half adult) were subjected to three environmental conditions: Noise, negative air ions, and positive direct electric fields. This study consisted of two experiments, one of which involved exposing rats to two levels of noise and three levels of negative air ion concentrations. The other experiment involved exposing rats to two levels of noise and three levels of electric field intensity variations. The data collected consisted of the time and error scores (average value of 10 trials for each rat) of rats running a modified Lashley Left-Right Maze with an escape from water motive.

A randomized-complete-block design with repeated measures was selected for statistical treatment by analysis of variance. In the cases where significant interaction terms appeared with significant main effects an additional statistic (Newman-Keuls) was used to facilitate interpretation of the main effects.

A new measure of learning based on the concept of negentropy as defined by information theory, and the concept of conservation of energy is exposed. Also a random walk model for choice behavior which simulates the rat maze system is proposed.

ACKNOWLEDGEMENT

The author wishes to express his appreciation to the many people who helped make this work possible. Without their patience, understanding and moral support, the task would have been difficult indeed.

Special thanks are extended to Dr. Richard A. Terry and Dr. Darrel G. Harden under whose astute guidance this work was done. Their comments and suggestions have materially enhanced this manuscript.

The author also wishes to acknowledge appreciation to the following:

Dr. Charles W. Bert for his helpful comments in proofreading the manuscript.

Dr. Bob L. Foote for his enthusiasm and considerable contribution in both time and ideas.

Dr. Edward F. Blick for his encouragement and support. His selfless dedication to his profession and sincere interest in his students have made the author's association with him a most rewarding and memorable experience.

Mrs. Shirly El-Attrache for her careful typing of the reading copy.

Very special thanks to the most indispensible help of all in any experimental effort, the laboratory assistants, Messers. Nazih Faddoul, Munir Kharma, Salim Bitar, Fouad Al-Kotob, and Ray Lieber.

A special note of appreciation is extended to the Director, Dr. Tom J. Love, Jr., and the faculty and staff of the School of Aerospace and Mechanical Engineering.

TABLE OF CONTENTS

Page

Chapter

Appendices

LIST OF TABLES

LIST OF ILLUSTRATIONS

THE EFFECTS OF NOISE, AIR IONS, AND ELECTRIC FIELDS ON LIVING SYSTEMS

CHAPTER I

INTRODUCTION

Living Systems and Combined Environmental Stresses

Information regarding the effects of combined environmental stresses on living systems is virtually non-existent. The very little that is known about combined stresses is the result of recent manned-space operations and therefore is not directly applicable to the earth environment of man-machine systems (transportation vehicles, farm equipment, industrial machniery, home and other appliances, etc.). Machines perform well only if the men operating them can perform their jobs satisfactorily. This fact, however, is often neglected due to the lack of data available to design engineers regarding the combined environmental effects and the optimal level of tolerances a particular system demands.

It is worth noting that better understanding of the combined environmental stresses on living systems will provide the required information to better define tolerance limits of man-machine systems consistent with the health and safety of the operator.

When the effects of environmental stresses on living systems are considered, the concept of "tolerances" should be made clear. Unlike most material structures, living systems do not usually proceed undisturbed to the point of chaotic collapse as increasing stresses are applied to them. The more common reaction is a progressive decrement of function (Fig. 1-1). Rather than a single numerical value analogous to the compression strength of concrete, a living system's tolerances can be better stated as a curve which relates applied stresses to some measurable performance or function. Then tolerances, as points along this curve, signify phenomena ranging from an awareness that the stress is present to extreme discomfort, from transient or temporary injury to permanent injury or death. Unfortunately, present knowledge does not allow the construction of such curves for most physiological stresses.

In recent years there have appeared various articles and research findings regarding the single effects of negative air ions (Davis, 1963), electric field intensity variations (Cristofv, 1964; Barron and Dreher, 1964; Moos, 1964; Sommer and Gierke, 1964) and noise (Cole, Mohr, Guild and Gierke, 1964; Eldred, Gannon and Gierke, 1955) on the living system. There does not exist, however, any study that deals with the combined effects of these environmental variables, and therefore the manner in which they may interact when imposed in combinations is not known.

Noise is a part of man's environment. For long it has been recognized as a source of annoyance, discomfort and fatigue (mental and eventually physical) and thus is a detriment to the performance of most living systems. Modern technology (jet travel, buses, trucks, subways, railroad trains, etc.) is causing man's environment to be noisier and it is only appropriate, therefore, that modern technology should seek to either eliminate, or counteract the effects of this by-product of its

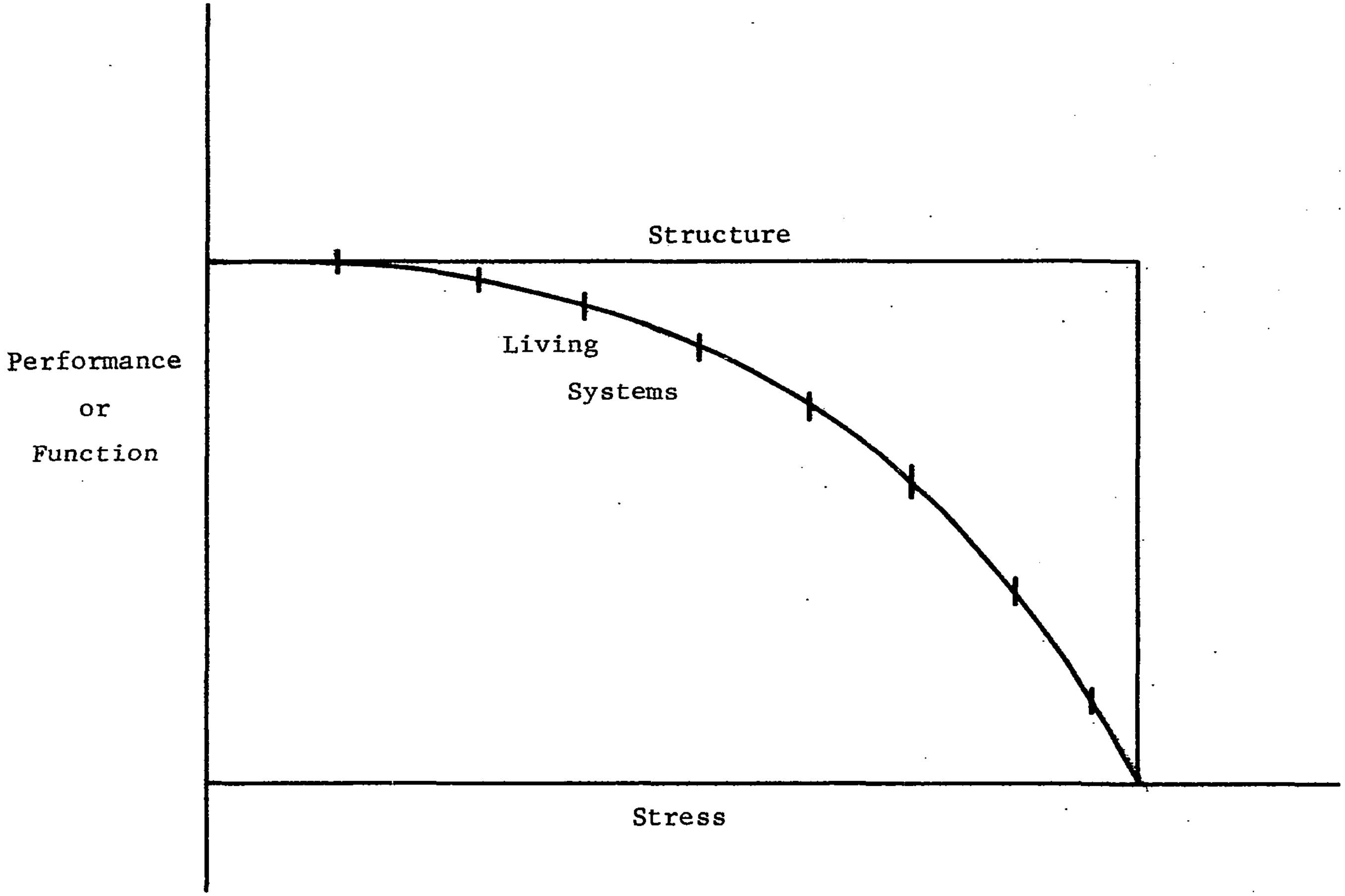


FIGURE 1-1. LIVING SYSTEMS' TOLERANCES TO STRESSES

advancement. The importance of the effects of noise on comfort and performance is now recognized in many ways; for example: the amount of research money currently devoted by the automobile industry to reduce the level of noise inside the car, the determination of airport facility locations in cities, the national television programs informing the public of the serious dangers caused by loud music usually encountered in night clubs, bars, etc., and the "quiet" criteria publicized in selling many of today's industrial and home appliances.

Like noise, air ions, and electric fields exist in man's environment. They form two of the most important components of the atmosphere and according to some investigators they are very essential for the development of life on earth. Both negative air ions and positive electric fields are believed to have beneficial effects on living systems, namely in ameliorating the effects of fatigue and stress. The important role that noise, air ion concentrations, and atmospheric electric fields play in the lives of living systems is evident. Therefore, a brief discussion of each of these environmental variables is now appropriate.

The Ionized Environment

Ions are always present in the gaseous mixture of the atmosphere, with a concentration that varies considerably over a wide range. This variation is due to changes in the weather, particularly the wind direction and the movement of air masses. In nature the principal sources of these ions are the cosmic ray radiation in high altitudes, together with radiation from radio-active materials in the earth's soil. There are other ionization sources such as the wind itself, but these are of lesser importance. For example, ions formed by cosmic and ultraviolet rays in high altitudes are sometimes brought all the way down to the earth's surface by strong air currents. Likewise, winds blowing over the surface of the earth will break up the space charge in that area, increasing the ions present that are formed by the radiation of the earth's soil. Ions have a relatively short life - a matter of minutes or a few hours. Most of the ions are lost by absorption when they hit the ground or a tree or some electrically grounded object. A few are lost by recombination with other ions of the opposite sign. Frequently, ions will change their character by attaching themselves to larger particles, such as moisture, dust, and spores. These are known as heavy ions and intermediate ions because of their size. Since their speed is inversely proportional to their size, they move at much slower speeds, and more ions can build up in an atmosphere that is contaminated.

There are many theories (Hicks, 1956) attesting to the therapeutic effects of ionized atmospheres on living systems. There does not exist, however, scientific knowledge that gives proof to the mechanism of negative or positive ions in relation to life and health. What is known is this: light negative ions are generally oxygen ions, and since it is oxygen in the air that the body absorbs, it is reasonable to suspect that negative ions may have an effect that is beneficial. Secondly, where air is pretty well confined, such as in closed rooms, positive ions will build up and decidedly predominate over negative ions, due principally to the difference in mobility of positive and negative ions. The negative ions, being smaller and faster, are lost to the walls of the enclosure more rapidly. As a high saturation of positive ions builds up, it neutralizes many of the negative ions, reducing their concentration, which some scientists believe is the cause of "stuffy" air. Thirdly, the exhaled breath is many times more positive than negative, which suggests that the negative ions are absorbed and positive ions are exhaled as unwanted. A great deal of biological work is now being done to try to unravel the mystery of the negative ion and its influence on the biological responses of living systems (Beckett, 1954).

So far, positive ions are only objectionable to the extent that they absorb and depress the level of negative ions. By themselves they do not appear to be harmful except in the presence of certain types of particles. One of these is tobacco smoke which becomes highly positively ionized and as a result more irritating. The mechanism of how this takes place is not known, although it is easy to measure in the laboratory the high affinity of tobacco smoke for positive ions. This is generally true of most smoke particles and can easily be demonstrated.

It has been suggested that there is a need for research to determine the effects of ionized atmospheres on living systems (Frey, 1959; Schaeffer, 1959; Wofford, 1962). Previous research indicates that ionization of the air has some effect on the following aspects of the behavior and physiology of living systems: Sensation (Bisa, 1938; Biss-Grafschaft, 1954), activity (Nielsen and Harper, 1954; Winsor and Beckett, 1958; Krueger and Smith, 1958; Vytchikova and Minkh, 1959; Herrington and Smith, 1935; Stanley, 1952; Tchijevsky, 1940), learning (Bauer, 1953; Jordon and Sokoloff, 1959), comfort and well being (McGurk, 1959; Yaglou, Benjamine, and Brant, 1933; Kornbleuh, Piersol and Speicher, 1959; Vytchikova and Minkh, 1959; Buetner, 1957; Rheinstein, 1960; Slote, 1962; Wofford, 1962), systemic effects (Ashiba, Kimura and Matsushima, 1941, 1942 and 1943; Winsor and Beckett, 1958; Minkh, 1957; McGurk, 1959), nervous system (Edstrom, 1934;

Vasiliev, 1951; Silverman and Kornblueh, 1957; Vail and Ivanov, 1960), circulatory system (Edstrom, 1934; Dessauer, 1931; Erban, 1958), skin (Edstrom, 1934; Busighina and Minkh, 1956; Tchijevsky, 1934; Winsor and Beckett, 1958; Muller, 1955), respiratory system (Dussert, 1959; Cauer, 1955 and 1958; Engles and Liese, 1954; Faibushevich, 1957; Fuks, 1955; Dolgachev, 1952, 1953, and 1954; Rohrer, 1952; Strasburger and Lampert, 1933; Landsmann, 1935), blood (Kuster and Frieber, 1941, 1942 and 1943; Landsmann, 1935; Rohrer, 1952; Schorer, 1952), wounds (Kornblueh, 1959; Minehart, David, McGurk, and Kornblueh, 1961), performance of vigilance tasks (Chiles, Fox, Rush and Stilson, 1962; Holcomb and Kirk, 1965).

The Atmospheric Electric Fields

Modern technological advances have placed man in new environments. The conquest of space has opened up experimental laboratories both in space and on the earth, in order to study what happens when living systems - plants, lower animals, and man - are exposed to modified environments. Of particular interest is the effect of exposure to electric fields which can, by virtue of transfer of energy to a living organism, potentially alter that system's future course.

The electrical field found in nature (discovered in 1752) is of variable strength; it changes suddenly and in an unpredictable fashion. However, the average value of the potential is about 120-700 v/m positive (directed downward) (Chalmere, 1949).

It is claimed that in enclosed spaces such as aircraft, space capsules, automobiles, trucks, buses, factories, office buildings, classrooms and underground, there exists shielded environments which have the physical qualities of a "Faraday Cage", that is, a space which has a field strength of zero, and thus is without the electric field found in nature. Therefore, if living systems have to perform certain tasks in such conditions, they become easily tired, exhausted, and drowsy, and shortly lose, either in part or altogether, their ability to perform properly. Professor G. Piccardi of the University of Paris and Director of the University Center for the Study of Fluctuating Phenomena in Florence, claims (Piccardi, 1967) that removing electrical charges from the air would render life painful, if not impossible. Addressing a group of scientists at Paris during the geophysical year, Dr. Piccardi said: "Some extremely significant experiments on this subject have been conducted in Switzerland; biological tests have been made in the Simplon Tunnel because is has 3,000 meters of high rock for protection from cosmic rays. Biological cultures have also been protected, either by iron armor or by lead armor, plus a layer of graphite, and only air devoid of electrical charges has been used. Life could not subsist in this medium. Everything dies there...". Professor Picardi continues: "...The statistics speak with impressive evidence if not with absolute certainty: the number of traffic accidents, of suicides, of pains from amputation, the time of biological reaction, the state of certain patients, the cases of sudden death, are related to this phenomena, (atmospheric electric field fluctuation)".

The history of atmospheric electricity was summarized in 1937 by Kahler. In his study Kahler states that when Alexander Von Humboldt gave his lectures on the atmosphere (later published in the book Kosmos, in the mid-nineteenth century) he recognized the importance of atmospheric electricity. He defined climate as "all modifications in the atmosphere which affect our senses markedly, namely, temperature, humidity, changes of the barometric pressure, wind, the amount of electric tension, the purity of the atmosphere or its admixture with more or less noxious gaseous exhalations, finally the degree of habitual transparency and clarity of the sky, which is not only important for the increased radiation of heat by the soil, the organic development of plants and the maturation of fruits, but also for the feelings of man and his entire mood". Hufeland also suspected a biologic effect of atmospheric electricity during the first half of the nineteenth century, as did others before him, but scientific research in this field was initiated by Elster and Geitel at the turn of the century. Except for a few speculative essays by Langen, Heinze, and Dull (1935 and 1941), according to Kahler, it was not until 1948 that meaningtul research in this area was begun.

Reiter (1960) gathered quantitive data from the literature up to 1960 to obtain statistic correlations between atmospheric electricity and the human responses.

The influence of electric fields is not as well represented in the literature. A Soviet popular science publication (Baikov, 1965) reports accelerated ripening of tomatoes in an electric field. Studies of behavioral patterns in mice in mild (8 to 12 v/m) ac electric fields have been carried out (Moos, 1964). As far as one can ascertain from the literature available, there has been scant work done on the exposure of animals and man to strong electric fields (Knickerbocker, Kouwenhoven and Barnes, 1967).

Noise

Noise is defined as any undesirable sound, even though it might be a meaningful one. The criterion of undesirability is based on the capacity of sound to disrupt communications, cause major injury to hearing (hearing loss), produce annoyance or discomfort, or reduce skilled performance.

Temporary hearing losses resulting from noise exposures are greater the higher the noise level, the longer the duration of exposure, and, within limits, the shorter the band-width within which the energy is concentrated. The effect is seen as a loss in auditory acuity, especially between 1000 and 6000 cps, and as a reduction in the loudness of the sound (Morgan, Cook, and Chapanis, 1963). Temporary hearing losses are produced rapidly and are maximum within about 7 minutes of exposure to pure tones ($\approx$ 100 db). Maximum loss from wide-band noise is longer and depends on whether or not it is steady-state noise. For steady-state noise in an industrial setting containing octave-band pressure levels of 90-100 db, an average loss in auditory acuity of 15 db for tones above 1000 cps can be expected following a 4-hour exposure period. Exposure to non-steady and intermittent noise of the same level has a lesser effect; a full working day of exposure to this kind of environment is required to produce an average temporary hearing loss of 5 db at frequencies above 1000 cps.

Recovery from temporary hearing loss depends on the duration of exposure, the nature of the sound, and the age of the person or animal so incapacitated. Recovery from non-impulsive sounds might require two to five times the duration of the exposure, depending on the nature of the sound. For example, normal workday exposure to octave-band levels of 95 db might require 2 - 5 days for complete recovery of normal auditory acuity, particularly in the 1000 - 6000 cps region, and a 30-minute exposure to a pure tone of 105 db might require 2 - 3 hours for complete recovery (Morgan et al., 1963; Covell, 1963).

Because noise is any undesirable sound, it may be thought of as related to a negative reaction or feeling of annoyance in the listener. The extent of his reaction will depend on the nature of his activity and the nature of the noise. Intermittent or other nonsteady noise and high-frequency components appear to be somewhat more annoying than other sounds. The annoyance value of the noise, however, does not seem to be a property of sound as such, but rather of the distracting power of the sound as a competitive stimulus. The habituation to a steady-state noise is more rapid than habituation to other sounds. Similarly, temporary hearing loss resulting from steady-state noise is more rapid than loss from intermittent noise because the intermittent periods of relative quiet permit some recovery.

The prediction of hearing damage risk is difficult because it depends on the individual person, on the spectral composition of the sound, and on the duration of exposure. One experiment carried out by the U.S.A.F. (Covell, 1963) subjected thirty-three cats to sound exposure. The animals were subsequently sacrificed and their inner ears examined for evidence of tissue injury. It was found that wide-band noise at 115 db for one-half hour produced mild injuries; for two-hour exposures there were severe injuries. The report concludes: "While considerable variability is evident in different specimens subjected to the same exposure for the same length of time, there persists a general trend for consistency of degree of injury in each group." Other work on the effects of noise on performance, although very scant, is available (Broadbent, 1953, 1954, 1957, 1958; Jerison, 1955, 1956; Jerison and Smith, 1955; Jerison and Wing, 1957; Jerison and Wallis, 1957; Kryter, 1950; Lazarus, Deese and Osler, 1952; Mackworth, 1950).

The Present Study

From the preceding information it is readily seen that the exact nature of biological activity when the organism is influenced by air negative or air positive ions or by positive or negative electric fields has not been clearly defined. It seems justifiable to say that critical or convincing evidence to substantiate the various therapeutic claims has so far not been adequately presented. There is a considerable quantity of conflicting experimental results, and no commonly accepted opinion has been established in medical circles to explain the various phenomena observed and described.

Most medical and biological research work with ionized air and electric fields has, up to the present, been concerned with looking for gross, preferably therapeutic effects. Tests have been carried out on the intact human or animal body both healthy and diseased, by placing it in the desired experimental atmosphere and noting physiological or psychological changes. Relatively few attempts were made to eliminate the simultaneous action of countless other physical and chemical stimuli (masking effects) upon such very complex biological systems. Furthermore these experiments were carried out on insufficient numbers of subjects to permit statistical corrections for these possible masking effects, as well as for the normal large physiological variations from the mean which any individual is likely to undergo. It is therefore hardly surprising that there is now no agreement on any significant effect directly attributable to ionized air or electric fields alone, nor has any attempt been made to determine its effects in conjunction with noise.

This study takes as its starting point the work and results of Sokoloff and Jordon (1959). In their study a multiple-T-maze with escape-from-water motive was used on 150 rats of an average age of 3 months and on 150 rats of an average age of 22 months to determine the effect of age differences on maze learning. The number of errors and the time scores on the group of old rats were about three times and two times greater respectively than those of the young rat group under normal atmospheric conditions; negative air ionization reduced considerably the number of errors and the time scores on the runs of the old rats. The present work has been expanded to include other environmental variables as well. These are electric field intensity variations and noise. In addition some organismic variables have been considered.

From the many organismic variables which one can choose to work with, age and sex were chosen. The choice was based upon practicality, ease of control, and significant relevance to performance as determined from the previous studies of Sokoloff and Jordon (1959) and Kornblueh, Piersol and Speicher (1958).

It has long been recognized that general principles of learning behavior are equally applicable to various species of animals, including man, when the circumstances in which they are placed are similar. According to Ernest R. Hilgard, "general principles of learning [are] applicable not only to the species studied but to the learning of other animals have been adapted in one way or another for use with human infants or adults."[1] Since we were interested to learn the effects of our experimental environments on man, we would have preferred to use man as the experimental subject. However, since it is difficult to find people who are able or willing to spend seven working hours in an experiment, since one can control the environment of animals but not of humans prior to experiment time, and since both the amount of laboratory space and the amount of funds would be prohibitive if humans were used, it was decided to use rats as the experimental subjects.

---

[1] S. S. Stevens (ed.), Handbook of Experimental Psychology, John Wiley and Sons, New York, 1951, p. 518.

CHAPTER II

METHOD

Experimental animals (rats) were subjected to three environmental conditions: Noise, negative air ionization and electric fields. The study consisted of two experiments. Experiment one involved noise and negative air ionization, and experiment two involved noise and electric fields. The two designs for statistical treatment by analysis of variance are shown in Figures 2-1 and 2-2. A King-Holtzman hybrid breed of rats obtained from the Stanley-Gumbrech Colony of the University of Oklahoma Medical Center Physiology Department at Oklahoma City, Oklahoma, was used.

The Rats. A total of 400 rats, half males and half females, were tested during the course of this study. Both males and females were divided into two age groups. The young group were 21 to 30 days old and weighed an average of 47.5 grams (females: 45 grams, males: 50 grams). The adult group were 90 to 100 days old and weighed an average of 170 grams (females: 150 grams, males: 190 grams). All rats were kept on Purina Laboratory Chow. The rats were kept in the animal facility of the Microbiology Building of the University two blocks away from the Laboratory. Ten rats (the statistical reasoning for choosing 10 rats for each test is given in Appendix A) were tested daily Monday through Friday for a period of eight weeks. For each test ten rats were transported to the laboratory by car at 9:00 a.m. Upon arrival, the rats were numbered by coloring them with Magic Markers (different

		N_0			N_1		
		I_0	I_1	I_2	I_0	I_1	I_2
S_1	A_1	X_{NISAR}					
	A_2						
S_2	A_1						
	A_2						

FIGURE 2-1. EXPERIMENT I DESIGN

		N_0			N_1		
		E_0	E_1	E_2	E_0	E_1	E_2
S_1	A_1	$X_{N_{E_{S_{A_{R}}}}}$					
	A_2						
S_2	A_1						
	A_2						

FIGURE 2-2. EXPERIMENT II DESIGN

colors were used for different color rats). After the marking, they were put into the experimental cage with all of the equipment turned off. At 1:00 p.m., the rats were given a swimming exercise by placing them individually in a water tank for five minutes. After the swimming exercise, each was returned to the experimental cage. At 2:00 p.m., the equipment was turned on consistent with the experimental condition of the day. If noise was one of the conditions imposed by the design, it was turned on at 6:00 p.m. At 7:00 p.m., all equipment was turned off; the rats were removed from their cage and put into a galvanized metal drum with a wire mesh bottom and open top, measuring 2 ft. in diameter and 3 ft. in height. Each rat was taken individually from the drum, placed in the water maze, and returned to the drum upon completion of the run (trial). This procedure was continued until all ten rats had completed ten runs (trials) each. At that time, the rats were sacrificed by the application of ether. Each group of ten rats was chosen at random and marked at random. Furthermore, the experimental condition was also randomly selected in order to eliminate experimenter bias.

The Water Maze. A modified Lashley Left-Right Maze was built for these trials from galvanized metal. The runways were four inches wide and two feet deep. The motive was escape-from-water which was approximately ten inches deep and 72 to 77 F (room temperature). The maze had four actual choice points 1, 2, 3, and 4. The ends of the blind alleys, a, b, c, and d, are regarded as four pseudo choice points to provide a full definition of the maze problem. Three metal non-retrace doors were located in positions shown in the maze floor plan in Figure 2-3. At the goal box, the rat climbed a built-in ramp and thus escaped.

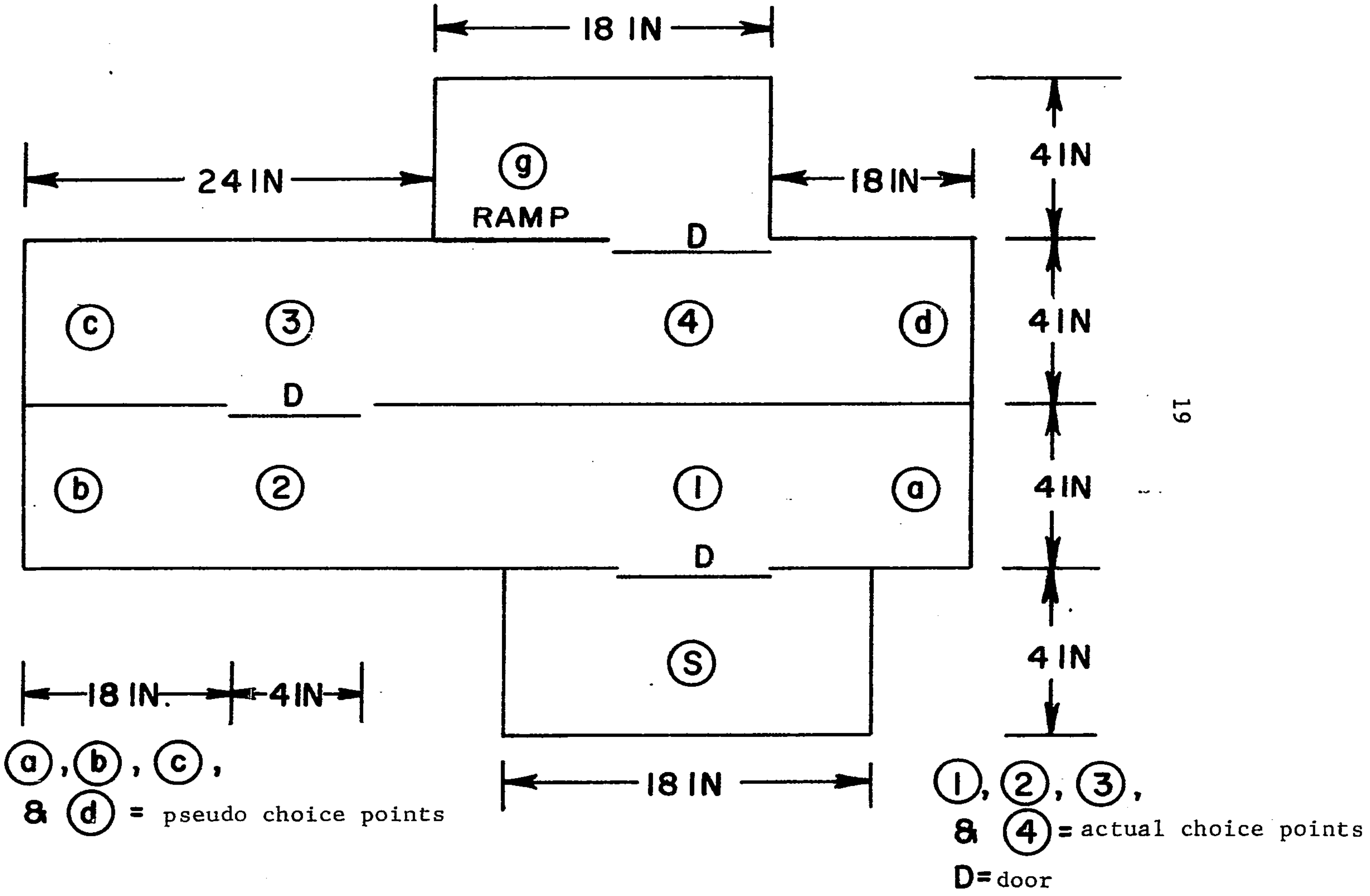


FIGURE 2-3. FLOOR PLAN OF MAZE

The Environmental Cage (Inner Cage). The inner cage was a 3 x 2 x 2 ft. enclosure placed on legs two feet high. The cage enclosure measured 3 x 2 x 2 ft. but the frame extended an additional two feet to accomodate the refuse tray and raise it to a convenient height. Most of the framework was constructed of Dexion steel angle frames. The floor and the top were constructed of a quarter inch wire mesh. The walls of the enclosure were constructed of Plexiglas and wood. (The wood was used at the corners as supporting frames.) The Plexiglas and the wood furnished the proper insulation between floor and roof. Four circular windows were cut (5½ in. from floor to center of hole), two on each side, to facilitate the installation of the ion generators. A sliding door, 12" x 7", was placed in the front wall. A quarter inch hole was drilled in the back wall to receive the spout of the water bottle. This arrangement is shown in Figure 2-4. The roof of the cage was attached to the negative pole of the power supply while the floor and the supporting structure were attached to the positive pole of the power supply and ground.

The Outer Cage. The outer cage was 5 x 3 x 6 ft. enclosure constructed of Dexion steel angle frames and quarter-inch wire mesh. The front wall, broken in the middle and hinged on both sides, provided swinging doors opening out. This cage provided the proper shielding from foreign electric fields present in the laboratory room and also shielded the experimenter from the strong electric fields imposed on the inner cage at different times of the experiment. This cage was also properly grounded. The door of this cage was connected to an on-off switch controlling the power supply so that when the door was opened, the power automatically cut off and the condenser discharged, thus providing personnel safety consistent with the regulations of the College of Engineering of the University.

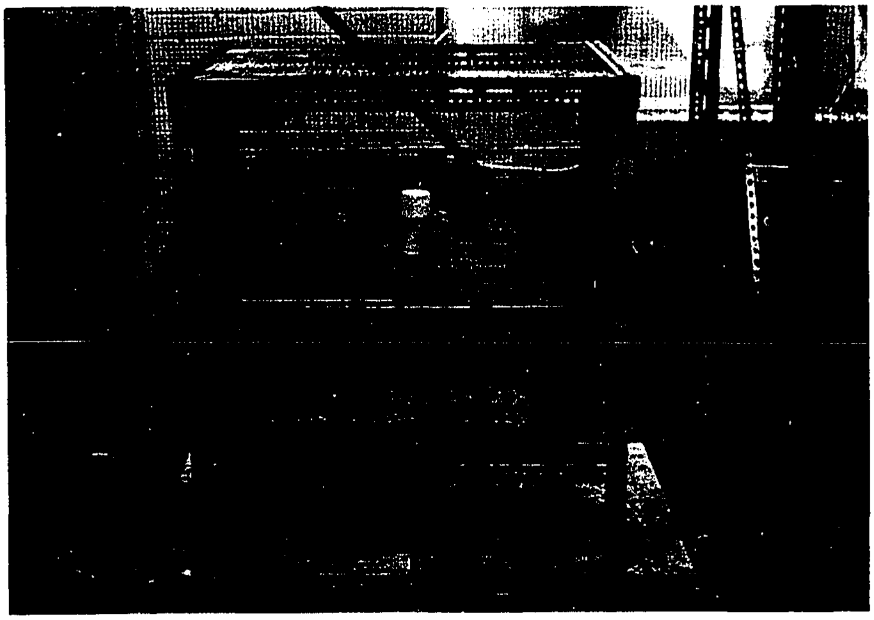


FIGURE 2-4. THE ENVIRONMENTAL CAGE

This design is shown in Figure 2-5.

INSTRUMENTATION

A. Negative Air Ionization. The negative air ionization was produced by negative ion generators. Four Dynamic Ion Air Mark VII negative ion generators manufactured by the Wesix Electric Heater Company of Burlingame, California were used. Low energy beta emission within the unit (generator) creates both positive and negative ions by collision with air molecules. Positive ions are absorbed within the element's head. Negative ions are forced out following lines of electro-static force, with distribution aided by means of a small fan. The standard generator unit can be plugged into any 110 volts AC outlet. Each unit has an ion output of over one billion negative ions per second. One of these units is shown in Figure 2-6.

B. Ion Concentration Measuring Equipment. A micro-micro-ammeter model 410, in conjunction with an ion probe, Model 403, both manufactured by Royco Instruments, Inc. were used to monitor negative ion concentration. A Honeywell Recorder Model No. Y153X12-V-II-III-6-A8 (B) (B5) was used to keep constant record of the current generated due to the particular experimental ion concentration used. This equipment is shown in Figure 2-7. An Alnor hot wire anemometer, Type 8500, No. 1131 was used to measure the velocity of the ions leaving the generators (Figure 2-8). These instruments furnished the required data for the computation of the negative air ion concentration inside the environmental cage by the use of the following equation:

$$N = \frac{I}{qAV} \qquad (1)$$

where

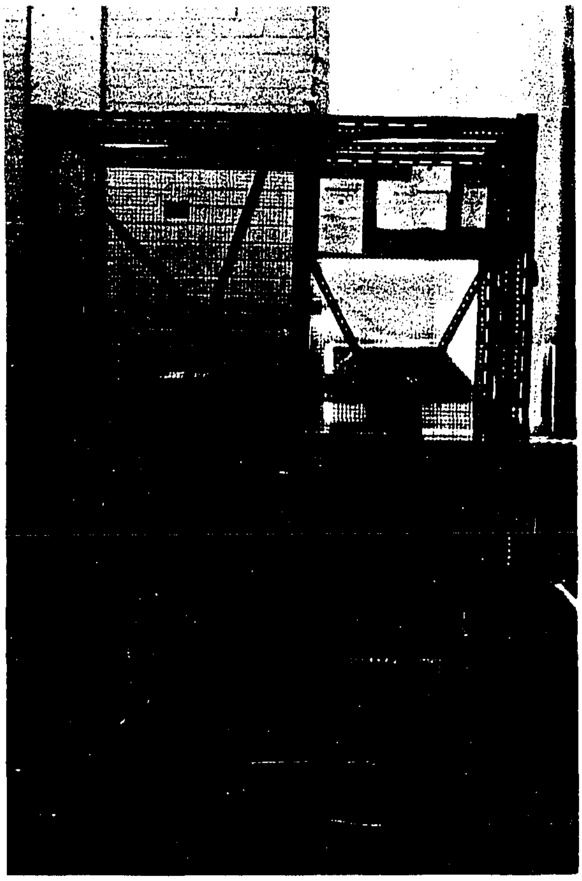


FIGURE 2-5. THE OUTER CAGE "SHIELD"

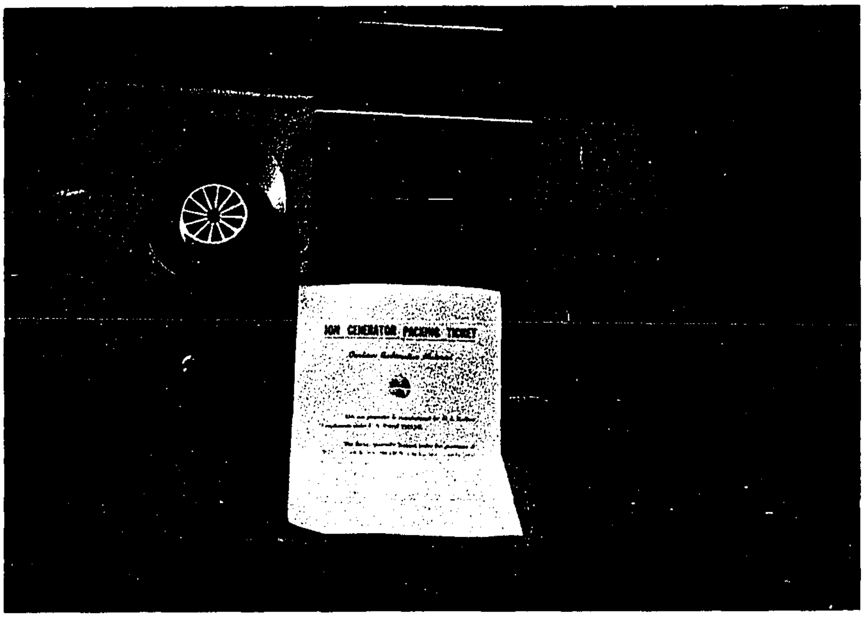


FIGURE 2-6. NEGATIVE ION GENERATOR

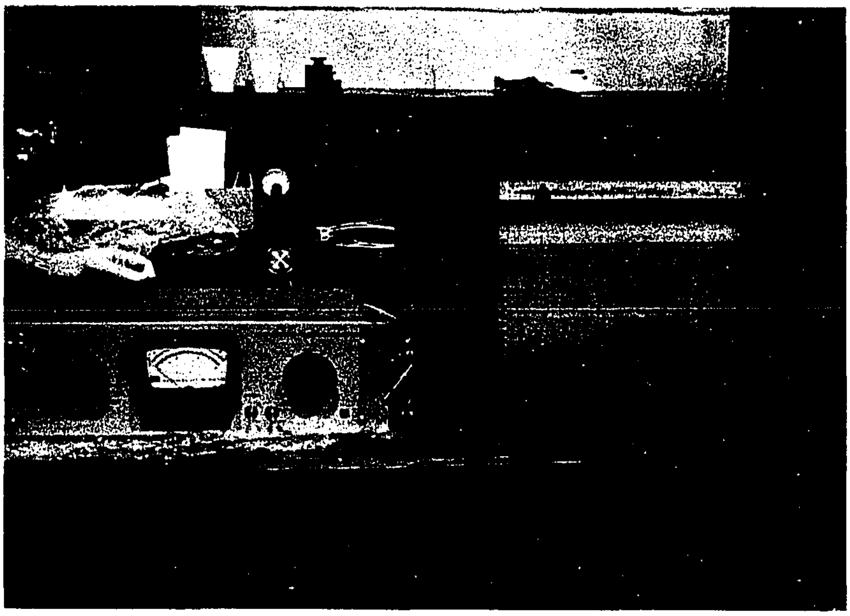


FIGURE 2-7. ION CONCENTRATION MEASURING EQUIPMENT

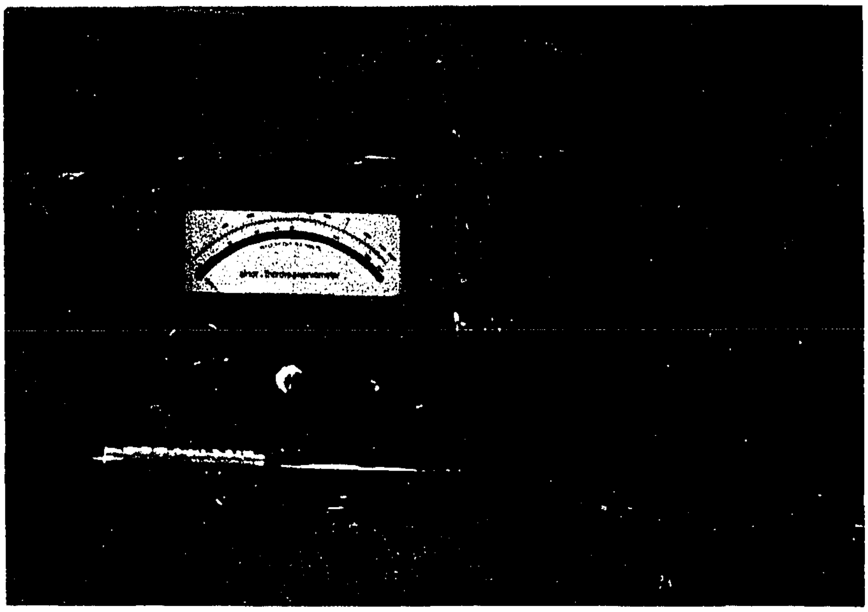


FIGURE 2-8. HOT WIRE ANEMOMETER

I = current produced by ions.

A = area of the probe surface.

$q = 1.6 \times 10^{-19}$ coulombs.

V = velocity of the ions.

Since the humidity of the atmosphere affects negative ion density, there was some fluctuation of about $\pm 5 \times 10^{5}$ negative ions per c.c. in the cage. In the laboratory, the humidity was thermostatically controlled by an air conditioning unit operating in conjunction with a steam heater. A permanent record of room temperature was kept by the use of a thermocouple placed inside the cage and connected to an L & N Speedomax W recorder (Figure 2-9).

C. Electric Field Generation. The electric field used in this study (Experiment two) was generated by a Biddle Transmitter and D.C. Proof Tester, Model 4, Serial 3308. The unit operates on 110 volts AC and it has a variable direct voltage output capacity of 15 Kilovolts (Figure 2-10).

D. Electric Field Measuring Instrumentation. The electric field intensity was measured by the use of (1) a standard voltmeter connected between the floor and the roof of the cage and (2) by a static voltmeter unit with Rustrak recorder forming an integral part of the unit (manufactured by RAWCO Instruments) and a probe made of standard circular plates, one of which is fixed and one of which rotates at a pre-calibrated speed (Figure 2-11). This particular unit was donated to us by L.T.V. Research Center of Dallas, Texas.

E. Time Measurement. The run time of each rat was recorded within 1/10 of a second accuracy by the use of a Lab-Chron 1400 electric timer which has a digital readout. This timer is shown in Figure 2-11.

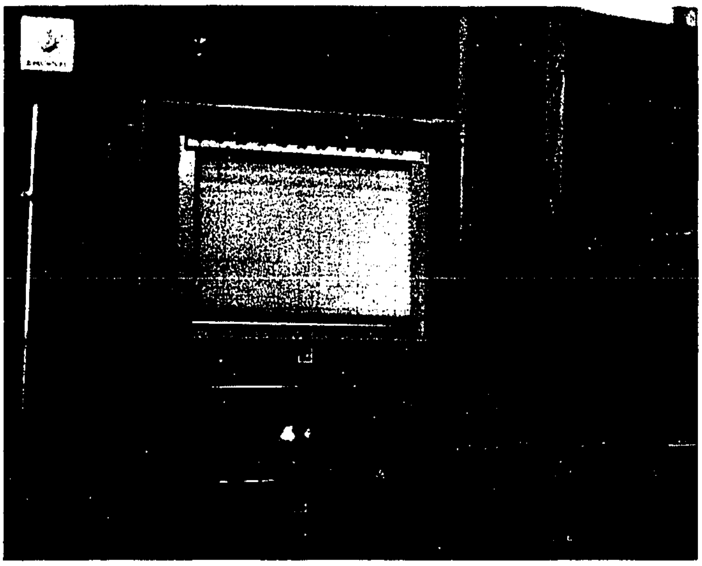


FIGURE 2-9. TEMPERATURE RECORDER

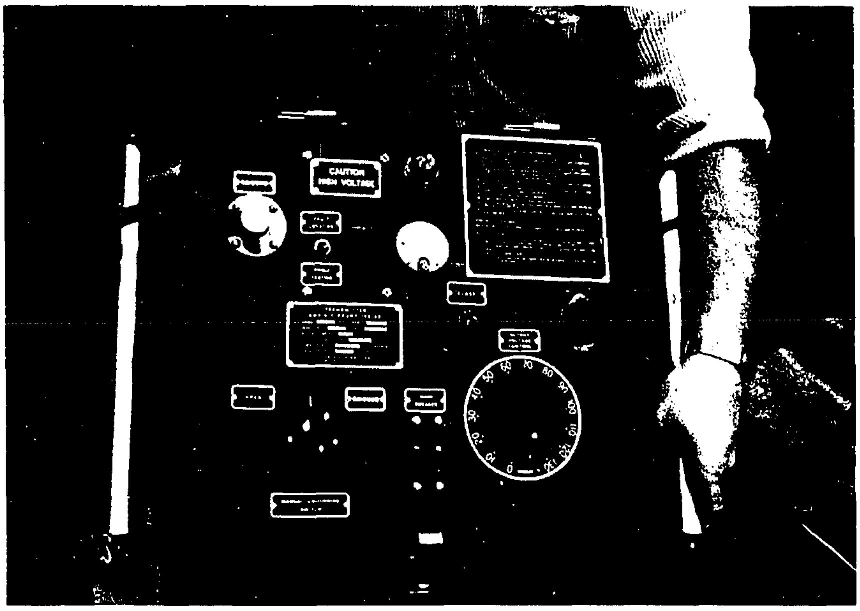


FIGURE 2-10. ELECTRIC FIELD GENERATOR

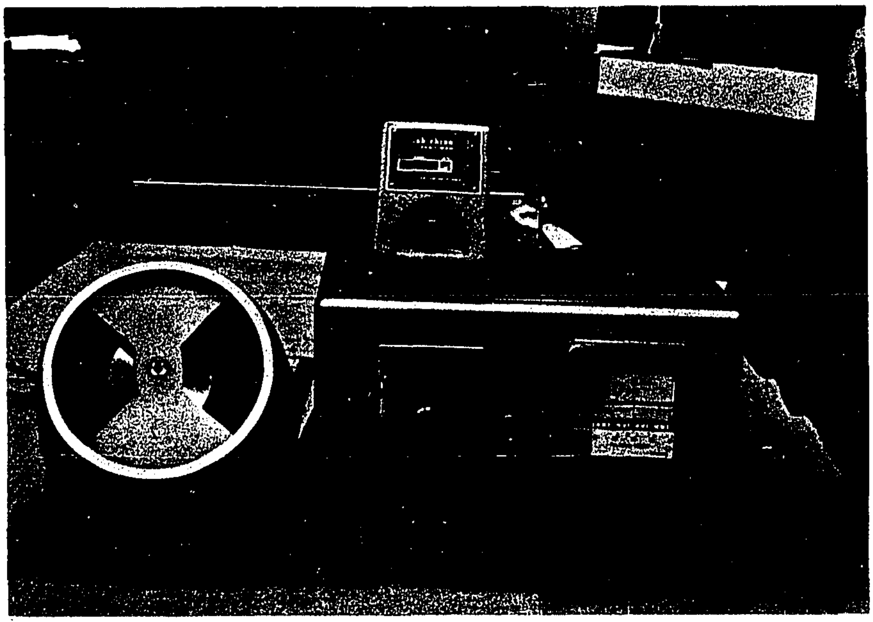


FIGURE 2-11. ELECTROSTATIC FIELD METER AND TIMER

F. Noise Generation. A closed-loop tape on which white noise had been recorded was played for a period of one hour when the experimental condition demanded it. A Sony Stereotape Recorder was used.

G. Noise Measuring Instrumentation. A frequency analyzer, Type 2107 manufactured by Bruel and Kjaer, shown in Figure 2-12, was used to calibrate the volume control on the tape recorder. A microphone attached to the analyzer was placed inside the environmental cage to measure the loudness and analyze the frequencies present, the noise level was kept at 90 db[2], and the frequencies present varied from 600 cps to 16,000 cps.

EXPERIMENTAL PROCEDURE

At 7:00 p.m. the investigator and the laboratory assistant went into the laboratory; the electric lights were turned on, and the equipment that was on for the particular experimental task was turned off. The rats were removed to the drum and allowed to stay there (for approximately 5 minutes) until the maze was filled with water to the proper level. Readings of the room temperature and relative humidity were taken and recorded on the data sheet. Then the testing procedure started.

The rats in sequence, one at a time, were placed in the starting box and allowed to proceed through the maze. The rats were scored according to the following method. If the rat turned to the right at choice point number one, it was given a W for wrong choice. If it turned to the left, it was given R for right choice. At choice point two, the rat was able to either turn to the right and go through the door to choice point three for which move it would be given R for right choice, or it could go

---

[2] Ref. 0.0002μ bar

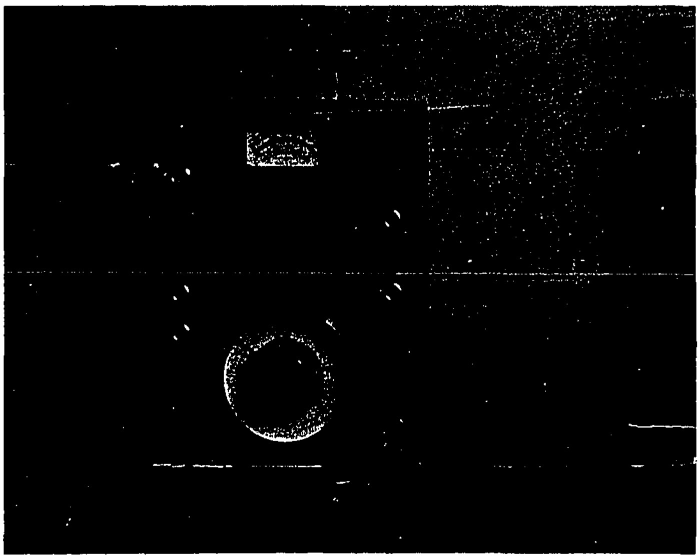


FIGURE 2-12. FREQUENCY ANALYZER

straight, for which move it would get W for wrong choice. Once at choice point three, the rat would have scored R by turning to the right, or W by turning to the left. At choice point four, the rat could turn to the left and get on the ramp, R, or it could go straight ahead for which it would get W. The doors were located as shown in Figure 2-3.

The first door was between the starting box and choice point one so that the rat could not return to the starting box once it had left it. The second door was located between choice point two and choice point three. Once the rat had crossed from choice point two to choice point three, it was not allowed to retrace its path. However, while at choice point two, the rat could loop between any of the true (actual) choice points one and two and the pseudo choice points a and b or any combination thereof. The rat was scored according to its initial move. For example, if the rat went from choice point one to choice point two, it was given R for right choice. At that point, if it retraced its path to choice point one or a without committing itself to either proceed to choice point three or b it was not penalized in scoring. This move was considered part of the rat's exploratory behavior prior to making a new decision. The same thing applied to the second half of the maze, namely choice points three and four, c and d. The third door was located between choice point four and the goal box in such a way that once the rat was in the goal box, it could not leave.

Therefore a rat would score R, R, R, R for a perfect run (trial) and W, W, W, W for committing a mistake - based on initial decision as explained above - at each choice point, or it would score any RW combination. It is obvious that based on the above criteria there are $2^4 = 16$ possible paths or events. For this discussion, an event is defined as the swim from the starting box to the goal box. (This point will be elaborated in later discussion.) The timer was started when the rat was put into the water at the starting box and it was stopped when the rat climbed the ramp at the goal box; the elapsed time thus measured constituted the time score of the rat. A separate data sheet (Figure 2-13) was kept for each rat.

While in the Laboratory the investigator and assistant did not converse except for the words "Ready?" prior to placing the rat in the water, "Go" when the rat was placed in the water at the starting box, and "Stop" when the rat climbed on the ramp in the goal box.

At the end of each run (trial), each rat was returned to the metal drum to await his next trail which did not occur until the other nine rats had completed theirs. After the fifth trial of all ten rats had been completed, the experiment was halted for a 10-minute break, then resumed until all ten rats had completed ten trials each. Each test lasted for a period of 3 to 4 hours depending upon the experimental condition and the group being tested. At the conclusion of each test, the maze was emptied by a pump and the laboratory was cleaned preparatory to the next day's test.

As mentioned earlier, the study was conducted in two experiments.

EXPERIMENT I

This experiment consisted of subjecting 240 rats to three different levels of negative ion concentrations under two different noise conditions. Noise Condition N_0 was the normal background noise of the laboratory and the surrounding neighborhood. N_1 was the condition under which

Rat No.

Expt. No.

Rm. Temp.

Exptl. Condition:

R. H.

Date

Trial No.	C.P.1	C.P.2	C.P.3	C.P.4	Number of Correct Responses	Time in Seconds
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
				Σ		
				average		

FIGURE 2-13. DATA SHEET

the taped white noise mentioned earlier was played. The three different levels of negative air ion concentrations were 1_o = the normal atmospheric environment of the laboratory (no measurable concentration of negative ions), condition $I_1 = 7 \times 10^6$ ions per c.c., and condition $I_2 = 7 \times 10^7$ ions per c.c. (see Figure 2-1).

EXPERIMENT II

Experiment II was identical to Experiment I except that the ion conditions were replaced by the electric field conditions (direct positive, i.e. directed downward, field). E_o was the condition of the laboratory environment with no field applied to the experimental cage. Condition E_1 = 1,600 volts per meter and condition E_2 = 16,000 volts per meter. It is obvious that conditions N_oE_o and N_1E_o were identical to conditions N_oI_o and N_1I_o respectively and, therefore, the scores for these 80 rats were used in both experiments. In other words, experiment II required only 160 rats. (Figure 2-2)

CHAPTER III

RESULTS

The objectives of this study as stated in Chapter II were to investigate the environmental effects of noise, negative air ion concentrations, and direct electric field intensity variations on the performance of rats in maze learning. Also included are two organismic variables: sex and age. Accordingly, the two experiments (Figures 2-1 and 2-2) discussed earlier were designed for statistical treatment by analysis of variance. This statistical procedure was programed for the IBM 360 computer. A listing and detailed description of the program and its routines is given in Appendix B.

The hypotheses we wish to examine stated in terms of the null hypotheses are:

A. <u>Experiment I</u>

1. H_o: $\mu_{N_o jk\ell} = \mu_{N_1 jk\ell}$

i.e., Regardless of the ion density conditions (j), differences in sex (k) and differences in age (ℓ), there are no significant differences in the performance of the rats in the maze because of the noise (i) condition imposed.

2. H_o: $\mu_{I_o ik\ell} = \mu_{I_1 ik\ell} = \mu_{I_2 ik\ell}$

i.e., Regardless of the noise condition, differences in sex, and differences in age, there are no significant differences in the performance of the rats in the maze because of the ion condition imposed.

3. H_o: $\mu_{S_1 ij\ell} = \mu_{S_2 ij\ell}$

i.e., Regardless of the noise condition, differences in ion density, and differences in age, there are no significant differences in the performance of the rats in the maze because of the differences in sex.

4. H_o: $\mu_{A_1 ijk} = \mu_{A_2 ijk}$

i.e., Regardless of the noise condition, differences in ion density, and differences in sex, there are no significant differences in the performance of the rats in the maze because of the differences in age.

B. <u>Experiment II</u>

1. H_o: $\mu_{N_0 j*k\ell} = \mu_{N_1 j*k\ell}$

i.e., Regardless of the electric field conditions (j)*, differences in sex (k) and differences in age (ℓ), there are no significant differences in the performance of the rats in the maze because of the noise (i) condition imposed.

2. H_o: $\mu_{E_0 ik\ell} = \mu_{E_1 ik\ell} = \mu_{E_2 ik\ell}$

i.e., Regardless of the noise condition, differences in sex, and differences in age, there are no significant differences in the performance of the rats in the maze because of the electric field condition imposed.

3. H_o: $\mu_{S_1 ij*\ell} = \mu_{S_2 ij*\ell}$

i.e., Regardless of the noise condition, differences in electric field intensity, and differences in age, there are no significant differences in the performance of the rats in the maze because of the differences in sex.

4. H_o: $\mu_{A_1 ij*k} = \mu_{A_2 ij*k}$

i.e., Regardless of the noise condition, differences in electric field intensity, and differences in sex, there are no significant differences in the performance of the rats in the maze because of the differences in age.

Although it is anticipated that certain interactions between the variables (both environmental and organismic) will occur, a formal statement of null hypotheses will not be given. This is due mainly to the uncertainty of the possible interpretation of these interaction terms, as well as the lack of a *a priori* knowledge of their distributions. However, the results of the analysis of variance treatments will be subject to detailed discussion.

For each experiment two ANOVA's were run, one analysis based on the correct response scores and one analysis based on the time scores. These scores were obtained from the last row of the data sheets (Figure 2-13) and are the average correct response and time scores over ten trials. A listing of these data are given in Appendix C. Tables 1 and 2 give the summary of the analysis for Experiment I, and Tables 3 and 4 give the summary of the analysis for Experiment II.

In order to simplify the statistical interpretation of the results (main effects as well as interaction terms) given in the analysis of variance summary Tables 1, 2, 3, and 4, the data were reorganized as shown in Figure 3-1. This was accomplished by making one data sheet for each trial, on which the performance of all ten rats was recorded in terms of their response (R or W) at each choice point and in terms of their run (trial) time. The time scores and the number of wrong choices per trial averaged for the 10 rats are then obtained from the last row of the new data sheets (Figure 3-1) and plotted vs. trial number as shown in Figures 3-2 through 3-17. Scoring the rats in terms of either the number of correct responses or the number of wrong responses at each choice point is arbitrary. Both scoring techniques would lead to the same results. If, for example, the number of incorrect responses (W's) is chosen, as in this case, the performance curve will be a decreasing function of W (wrong, or incorrect response), and if the number of correct responses (R) is chosen, then the performance curve will be an increasing function of R (right, or correct response).

It must be noted that each of the graphs presented here represents one level of the sex-age condition and the two levels of the noise condition with ion density variation (Experiment I) or electric field intensity variation (Experiment II) as a parameter. Therefore each set of four graph sheets (for each experiment there are eight graph sheets - four for the average error scores and four for the average time scores) provides adequate information to allow comparison of main effects as well as the interaction effects.

TABLE 1

Summary of Integrated Analysis of Variance

(Experiment I - Error Scores)

Source of Variation	df	MS	F
Noise (N)	1	0.280	1.22
Ions (I)	2	1.410	6.50**
Sex (S)	1	2.50	11.17**
Age (A)	1	2.18	9.27**
NxIxSxAxR	216	0.229	
NxI	2	0.68	2.970
NxS	1	0.0026	0.0113
NxA	1	0.0135	0.0588
IxS	2	0.253	1.103
IxA	2	0.02615	0.1140
SxA	1	1.41	6.15**
IxSxN	2	0.088	0.386
IxAxN	2	0.496	2.164
SxAxN	1	1.21	5.628**
SxAxI	2	0.655	2.85
SxAxIxN	2	0.43	1.903

** significant at the 0.01 level

TABLE 2

Summary of Integrated Analysis of Variance

(Experiment I - Time Scores)

Source of Variation	df	MS	F
Noise (N)	1	13.00	0.0278
Ions (I)	2	1826.4	3.909*
Sex (S)	1	1294.5	2.77
Age (A)	1	4.31	0.0092
NxIxSxAxR	216	467.18	
NxI	2	537.81	1.151
NxS	1	1866.2	3.994*
NxA	1	1762.56	3.77
IxS	2	2916.15	6.24**
IxA	2	4269.05	9.137**
SxA	1	76.31	0.163
IxSxN	2	668.62	1.43
IxAxN	2	1271.06	2.72
SxAxN	1	245.69	0.525
SxAxI	2	686.6	1.469
SxAxIxN	2	956.86	2.048

** significant at the 0.01 level

* significant at the 0.05 level

TABLE 3

Summary of Integrated Analysis of Variance

(Experiment II - Error Scores)

Source of Variation	df	MS	F
Noise (N)	1	0.002	0.009
Electric Field (E)	2	2.08	9.06**
Sex (S)	1	0.06	0.27
Age (A)	1	2.34	10.19**
NxExSxAxR	216	0.229	
NxE	2	0.152	0.66
NxS	1	0.0003	0.0013
NxA	1	0.108	0.471
ExS	2	0.462	2.01
ExA	2	0.258	1.12
SxA	1	0.0304	0.132
ExSxN	2	0.0409	0.178
ExAxN	2	0.157	0.688
SxAxN	1	0.477	2.07
SxAxE	2	0.282	1.23
SxAxExN	2	0.099	0.433

** significant at the 0.01 level

TABLE 4

Summary of Integrated Analysis of Variance

(Experiment II - Time Scores)

Source of Variation	df	MS	F
Noise (N)	1	344.07	1.267
Electric Field (E)	2	345.36	1.272
Sex (S)	1	4018.51	14.8**
Age (A)	1	0.190	0.000699
NxExSxAxR	216	271.55	
NxE	2	217.55	0.80
NxS	1	541.30	1.99
NxA	1	7.600	0.0279
ExS	2	266.5	0.98
ExA	2	24.60	0.0906
SxA	1	1103.0	4.063*
ExSxN	2	3005.90	11.072**
ExAxN	2	1467.35	5.405**
SxAxN	1	1311.80	4.832*
SxAxE	2	28.85	0.106
SxAxExN	2	534.95	1.97

** significant at the 0.01 level

* significant at the 0.05 level

Trial No.: ______ Expt. No. ______ Exptl. Cond. ______

Rat No.	C.P.1	C.P.2	C.P.3	C.P.4	Time	Number of Wrong Choices
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
				Σ		
				average		

FIGURE 3-1. REORGANIZED (NEW) DATA SHEET

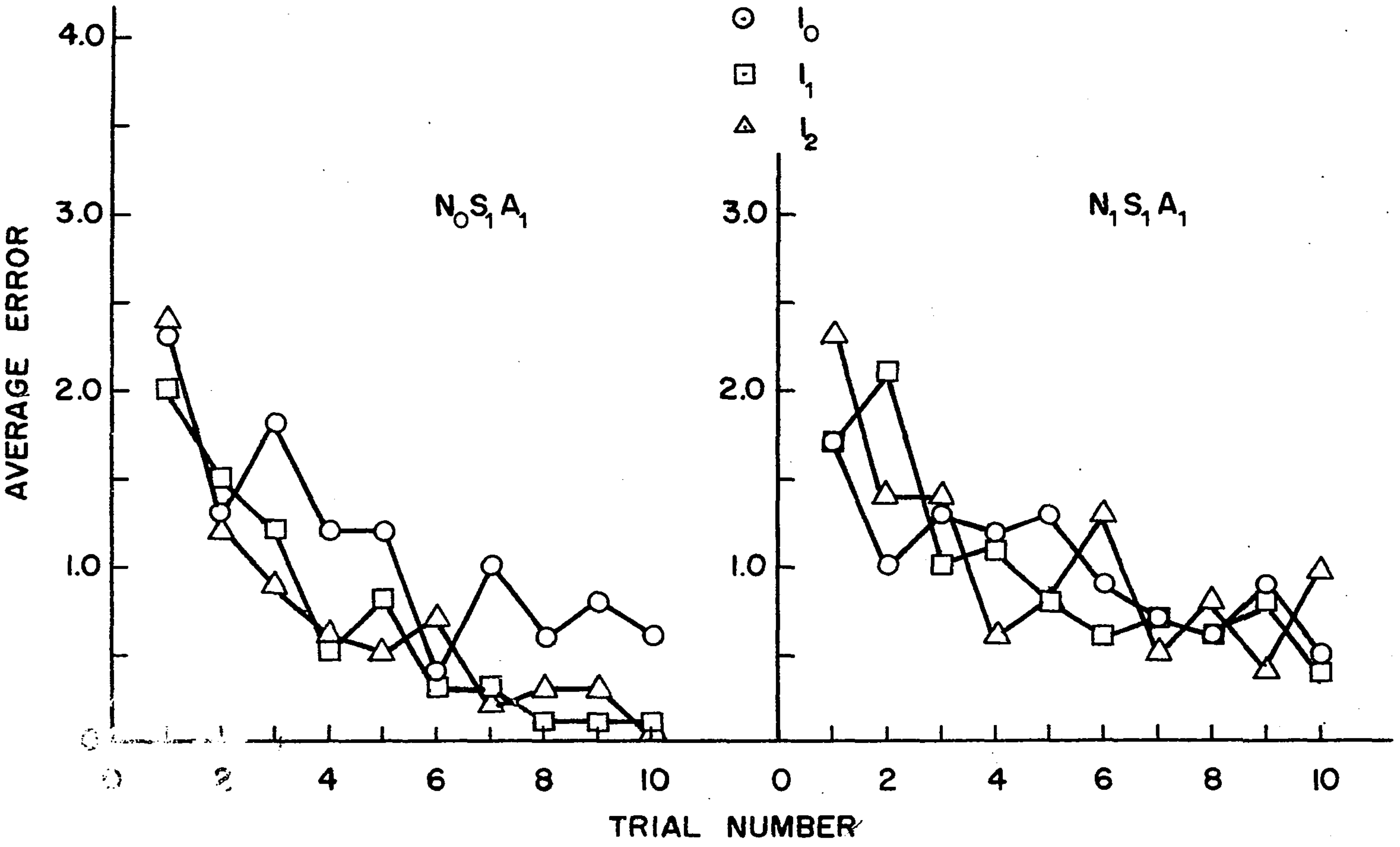


FIGURE 3-2. AVERAGE ERRORS FOR YOUNG MALES FOR EACH OF THREE LEVELS OF ION DENSITY UNDER EACH NOISE CONDITION

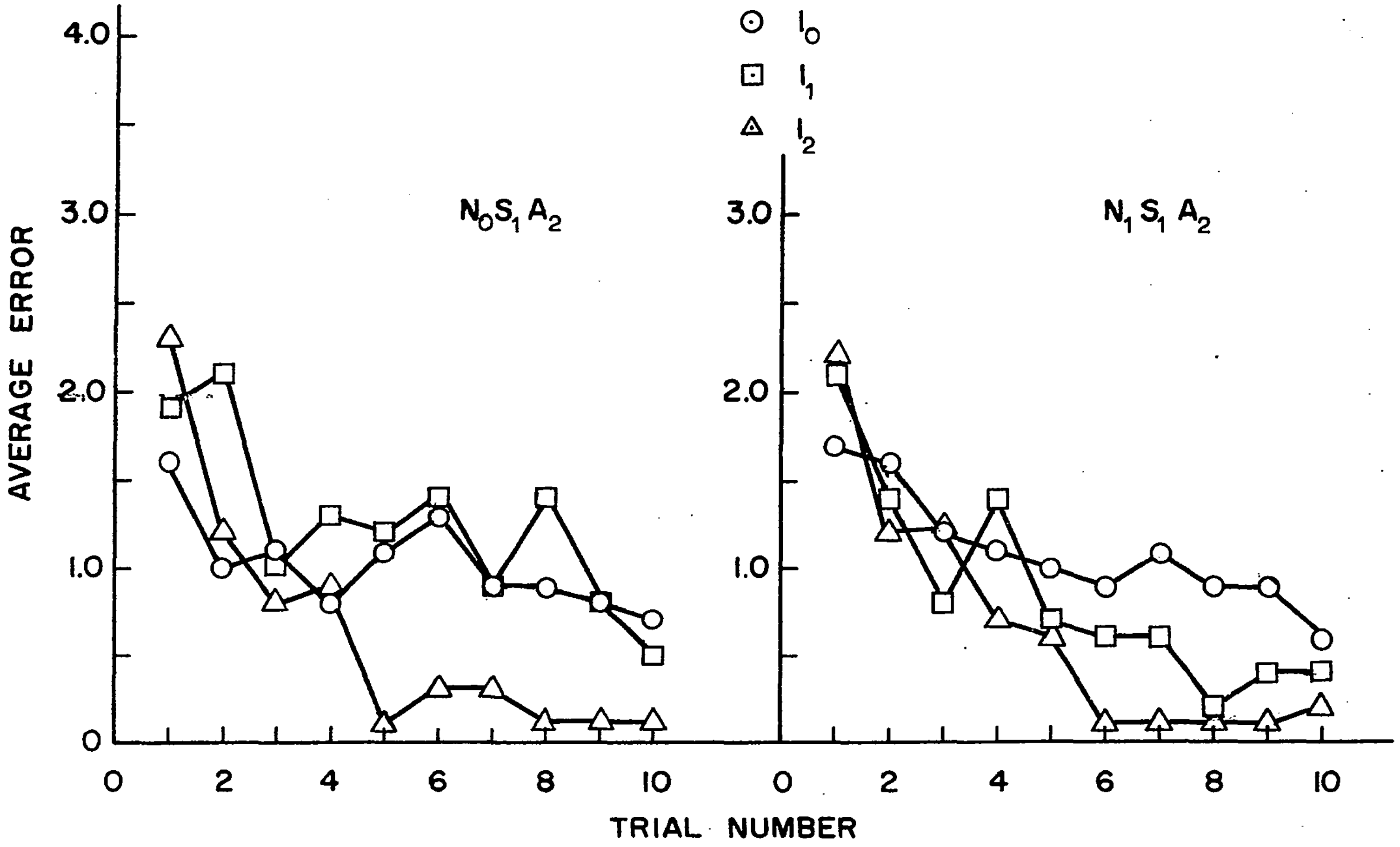


FIGURE 3-3. AVERAGE ERRORS FOR ADULT MALES FOR EACH OF THREE LEVELS OF ION DENSITY UNDER EACH NOISE CONDITION

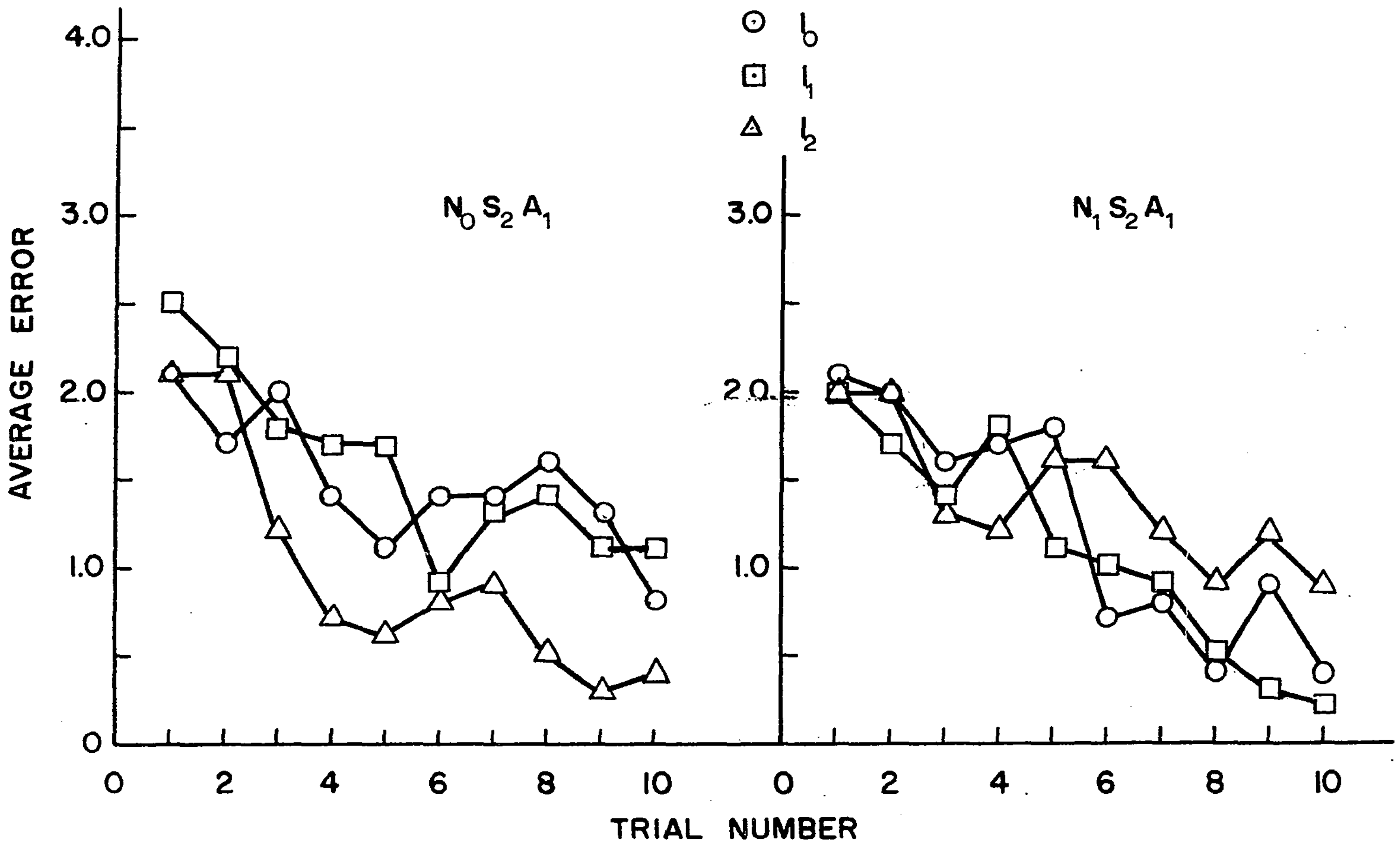


FIGURE 3-4. AVERAGE ERRORS FOR YOUNG FEMALES FOR EACH OF THREE LEVELS OF ION DENSITY UNDER EACH NOISE CONDITION

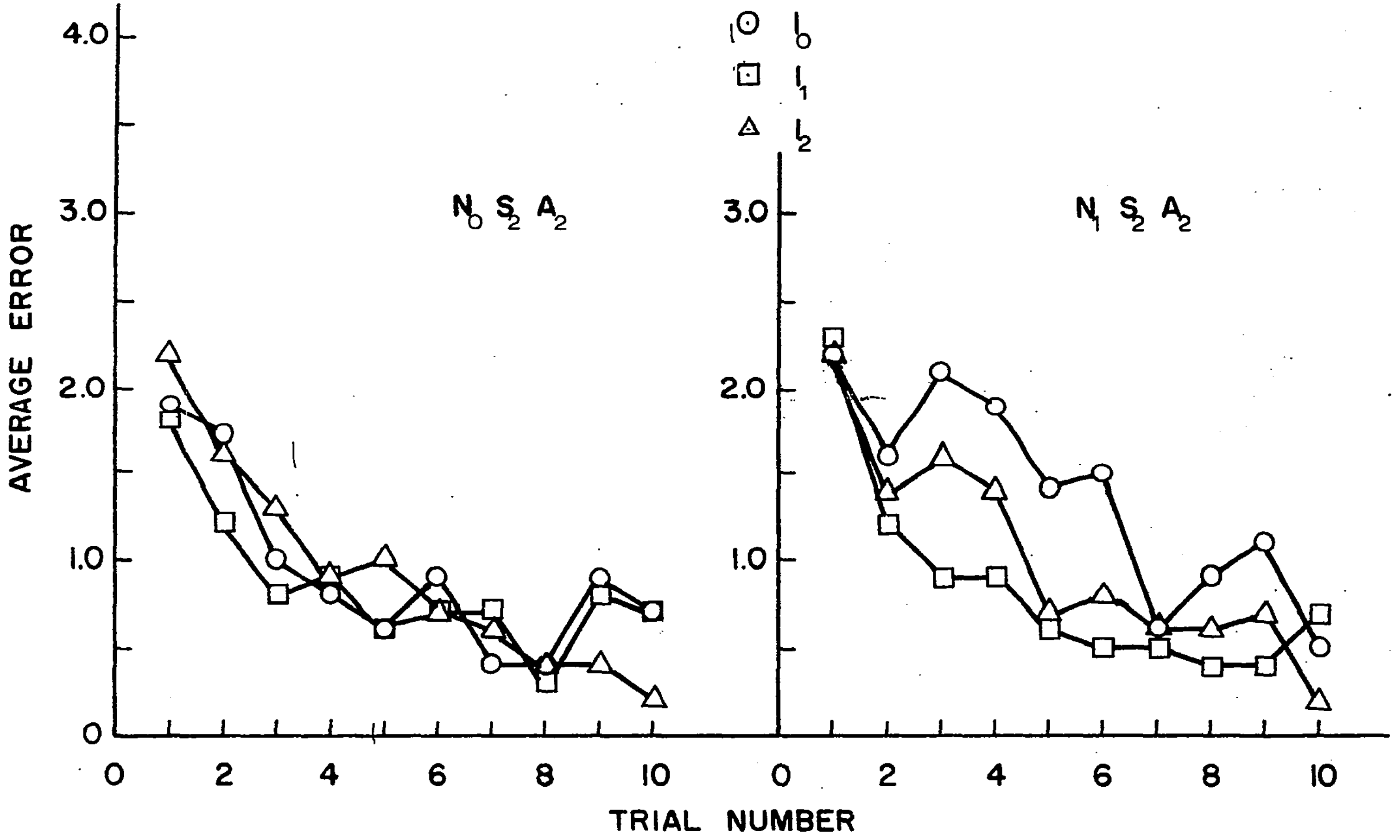


FIGURE 3-5. AVERAGE ERRORS FOR ADULT FEMALES FOR EACH OF THREE LEVELS OF ION DENSITY UNDER EACH NOISE CONDITION

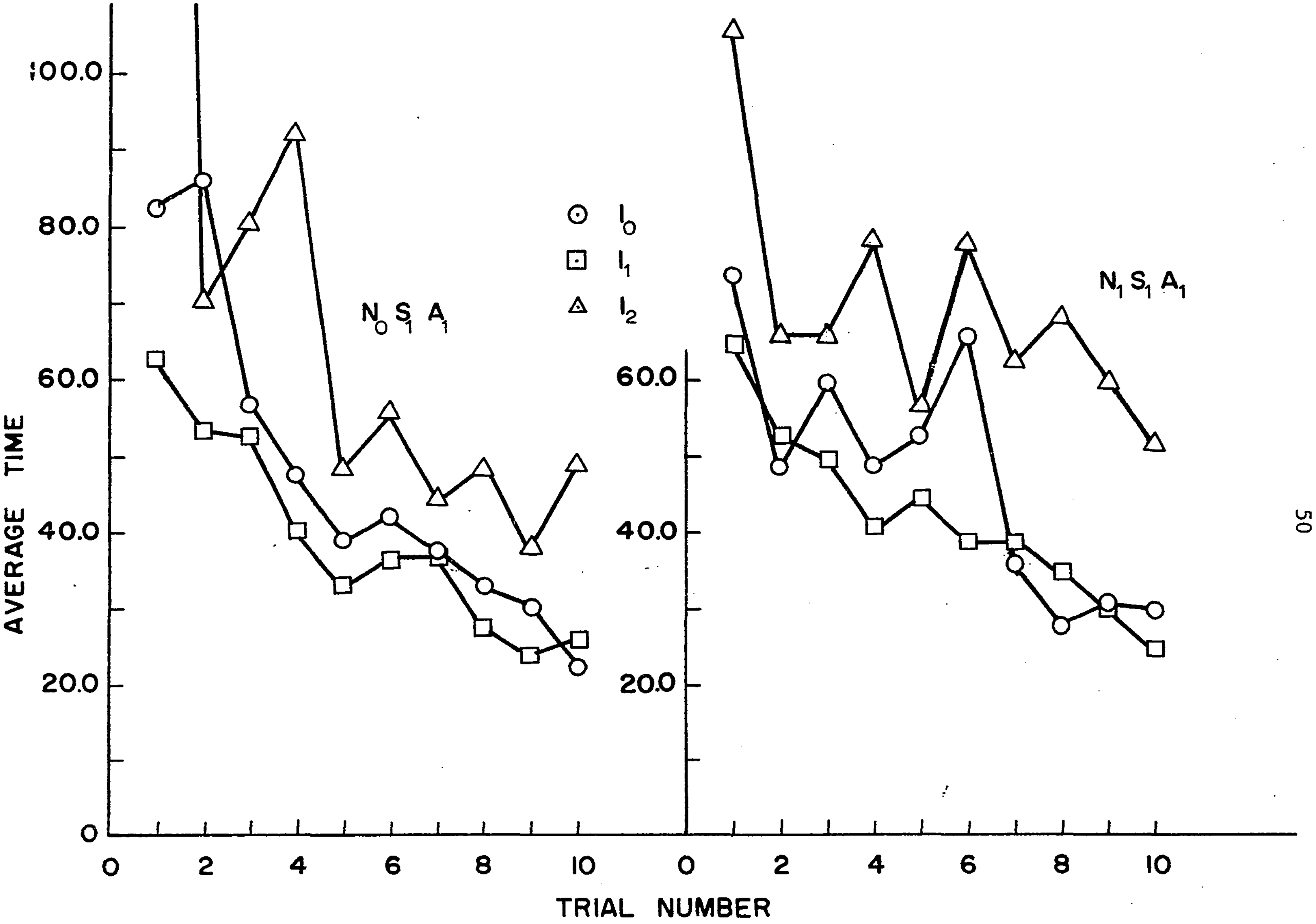


FIGURE 3-6. AVERAGE TIME FOR YOUNG MALES FOR EACH OF THREE LEVELS OF ION DENSITY UNDER EACH NOISE CONDITION

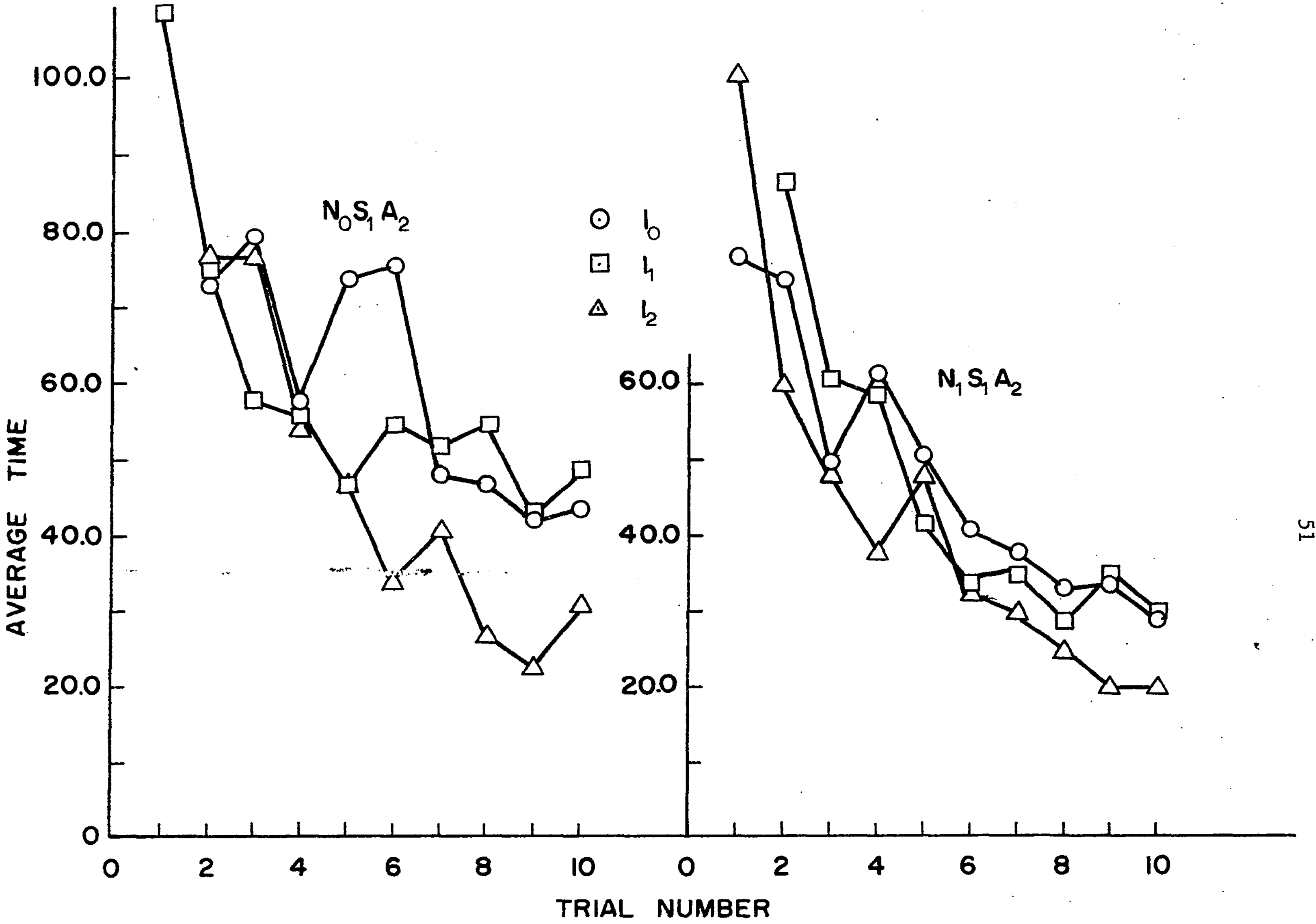


FIGURE 3-7. AVERAGE TIME FOR ADULT MALES FOR EACH OF THREE LEVELS OF ION DENSITY UNDER EACH NOISE CONDITION

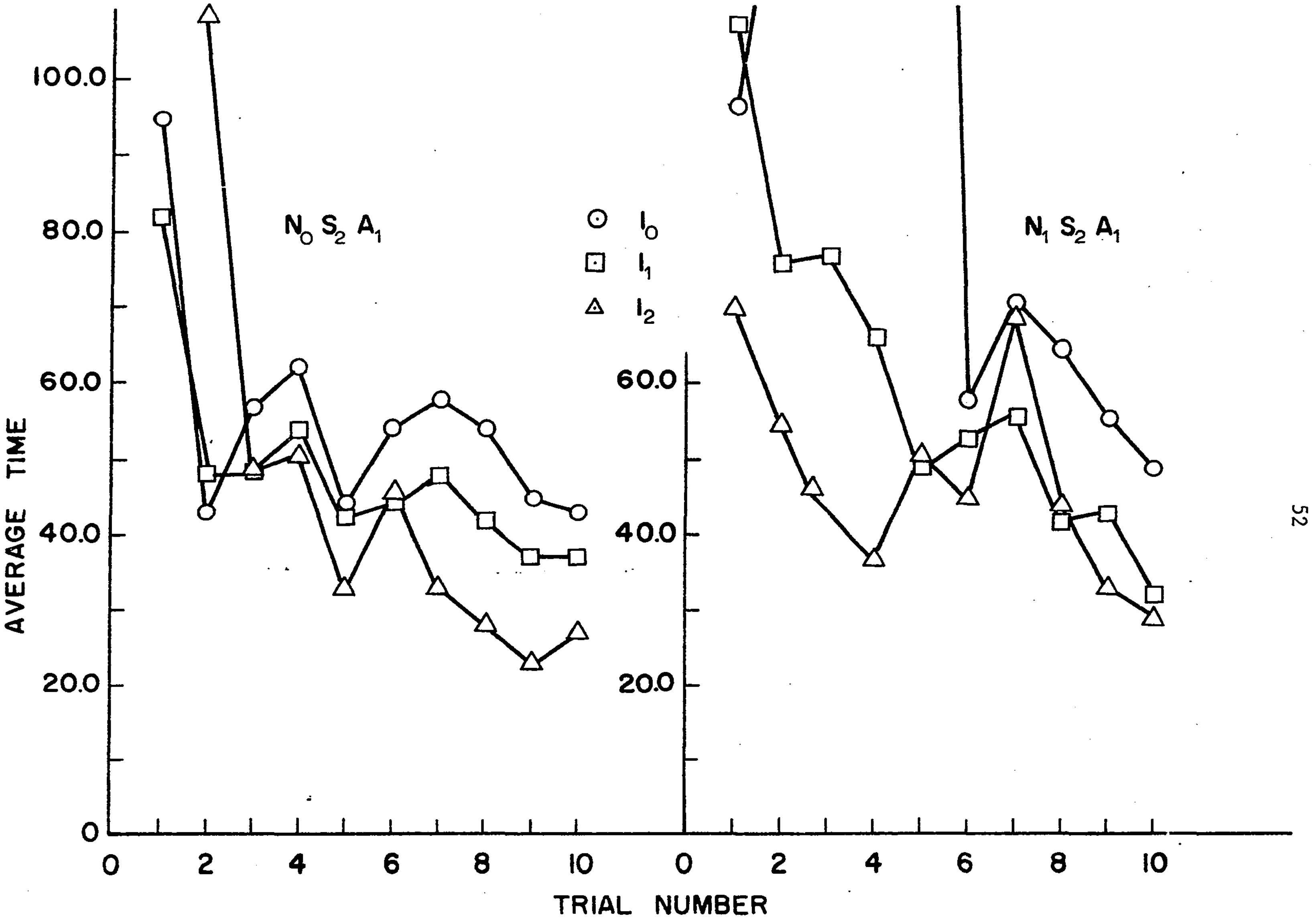


FIGURE 3-8. AVERAGE TIME FOR YOUNG FEMALES FOR EACH OF THREE LEVELS OF ION DENSITY UNDER EACH NOISE CONDITION

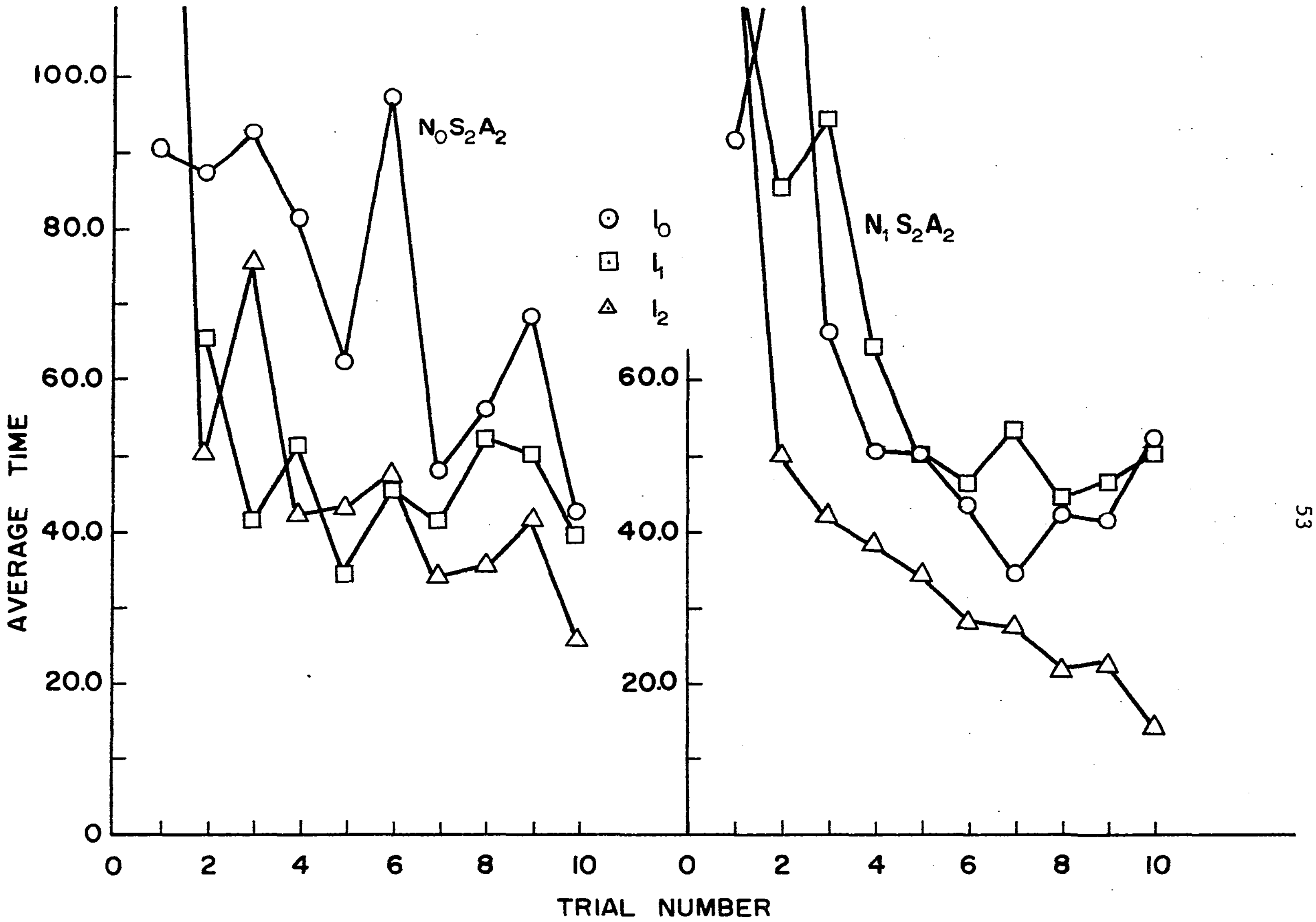


FIGURE 3-9. AVERAGE TIME FOR ADULT FEMALES FOR EACH OF THREE LEVELS OF ION DENSITY UNDER EACH NOISE CONDITION

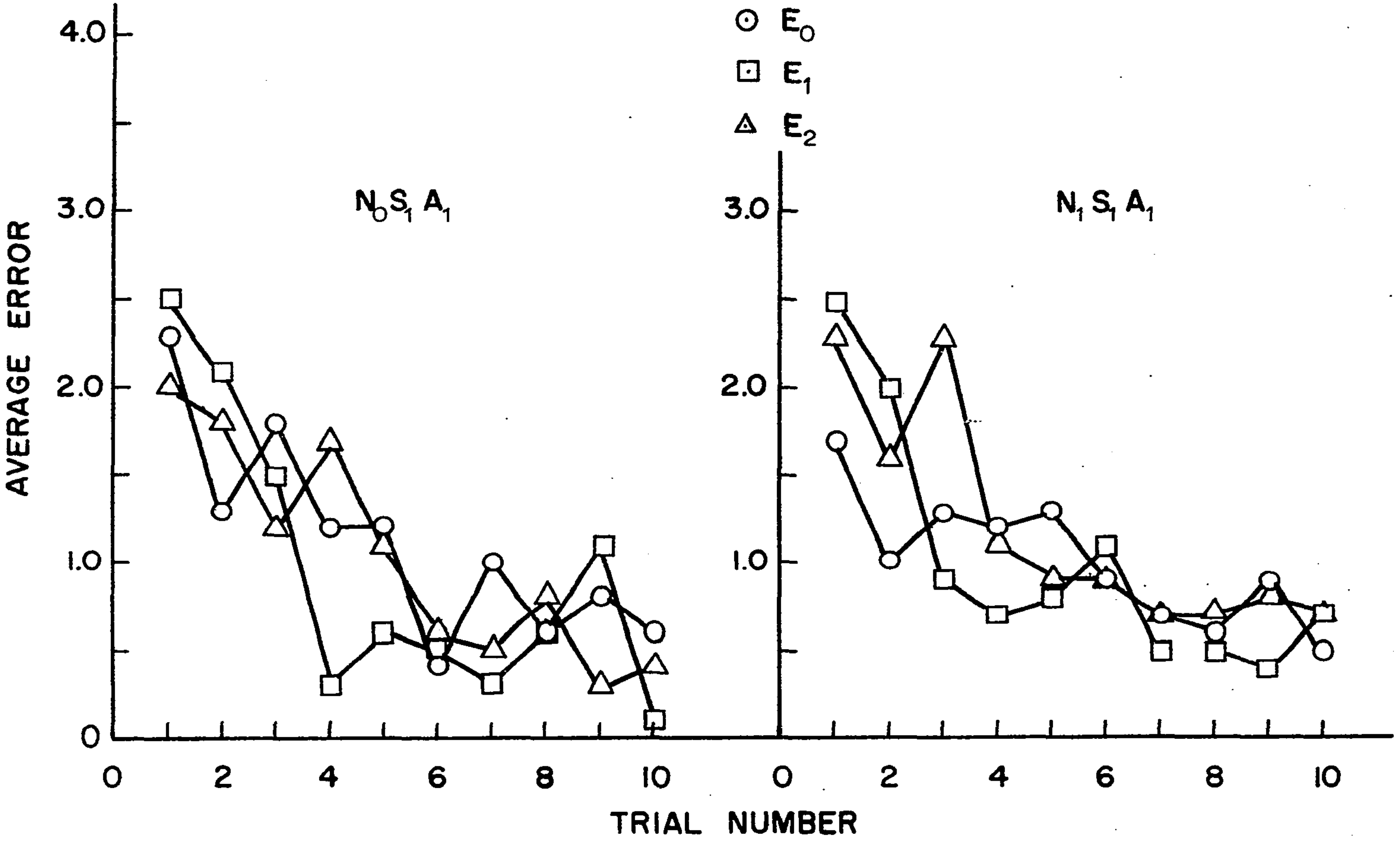


FIGURE 3-10. AVERAGE ERRORS FOR YOUNG MALES FOR EACH OF THREE LEVELS OF ELECTRIC FIELD INTENSITY UNDER EACH NOISE CONDITION

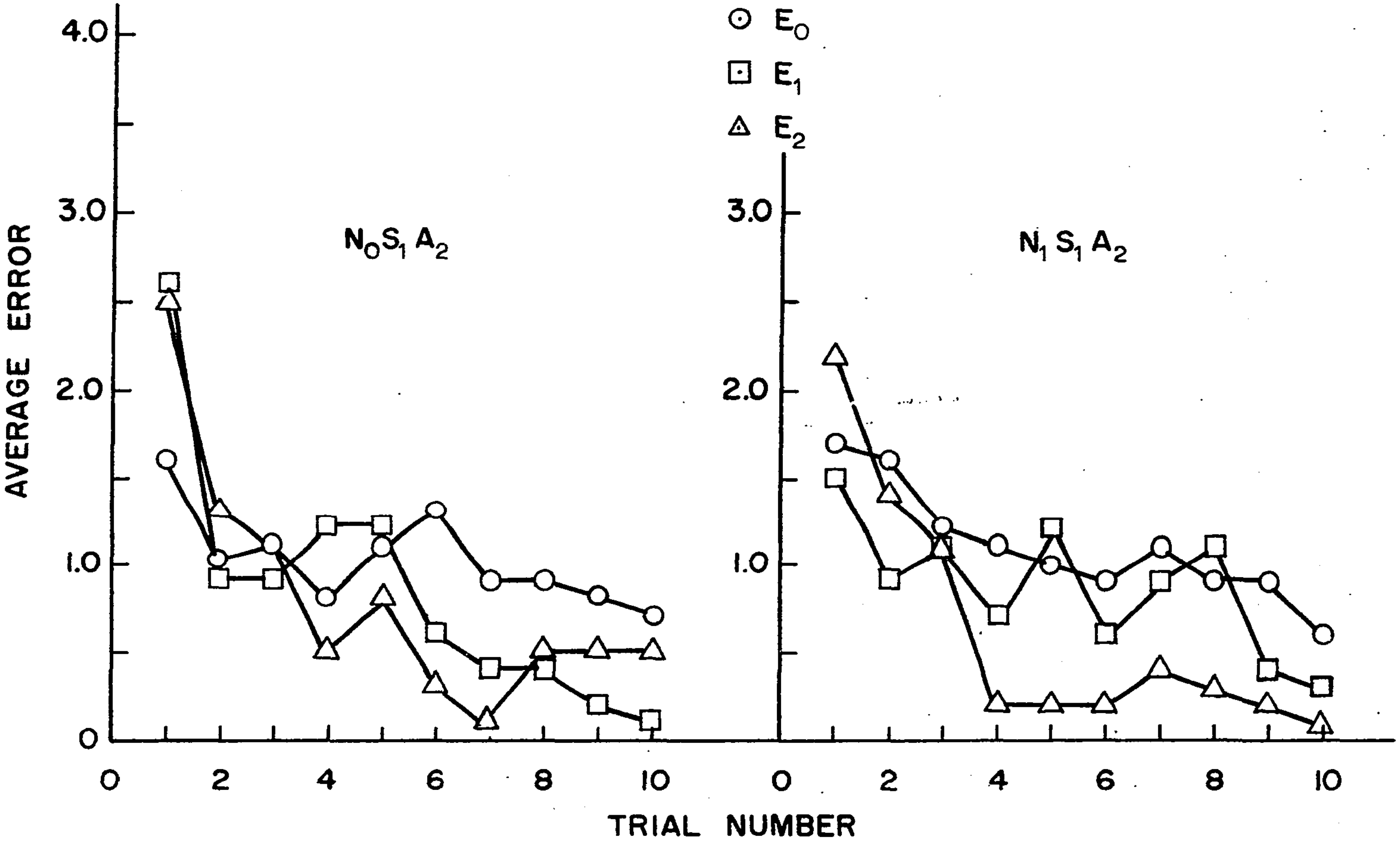


FIGURE 3-11. AVERAGE ERRORS FOR ADULT MALES FOR EACH OF THREE LEVELS OF ELECTRIC FIELD INTENSITY UNDER EACH NOISE CONDITION

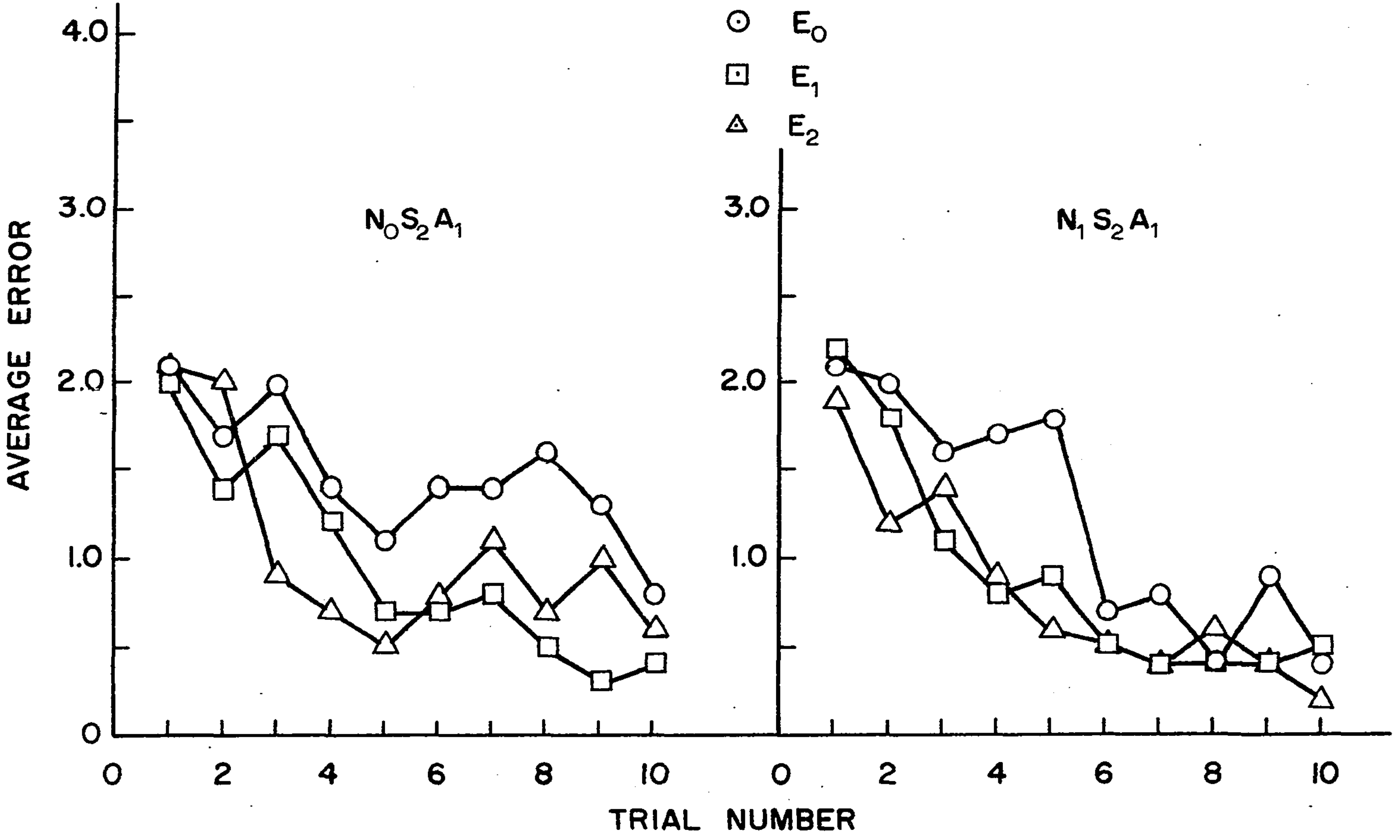


FIGURE 3-12. AVERAGE ERRORS FOR YOUNG FEMALES FOR EACH OF THREE LEVELS OF ELECTRIC FIELD INTENSITY UNDER EACH NOISE CONDITION

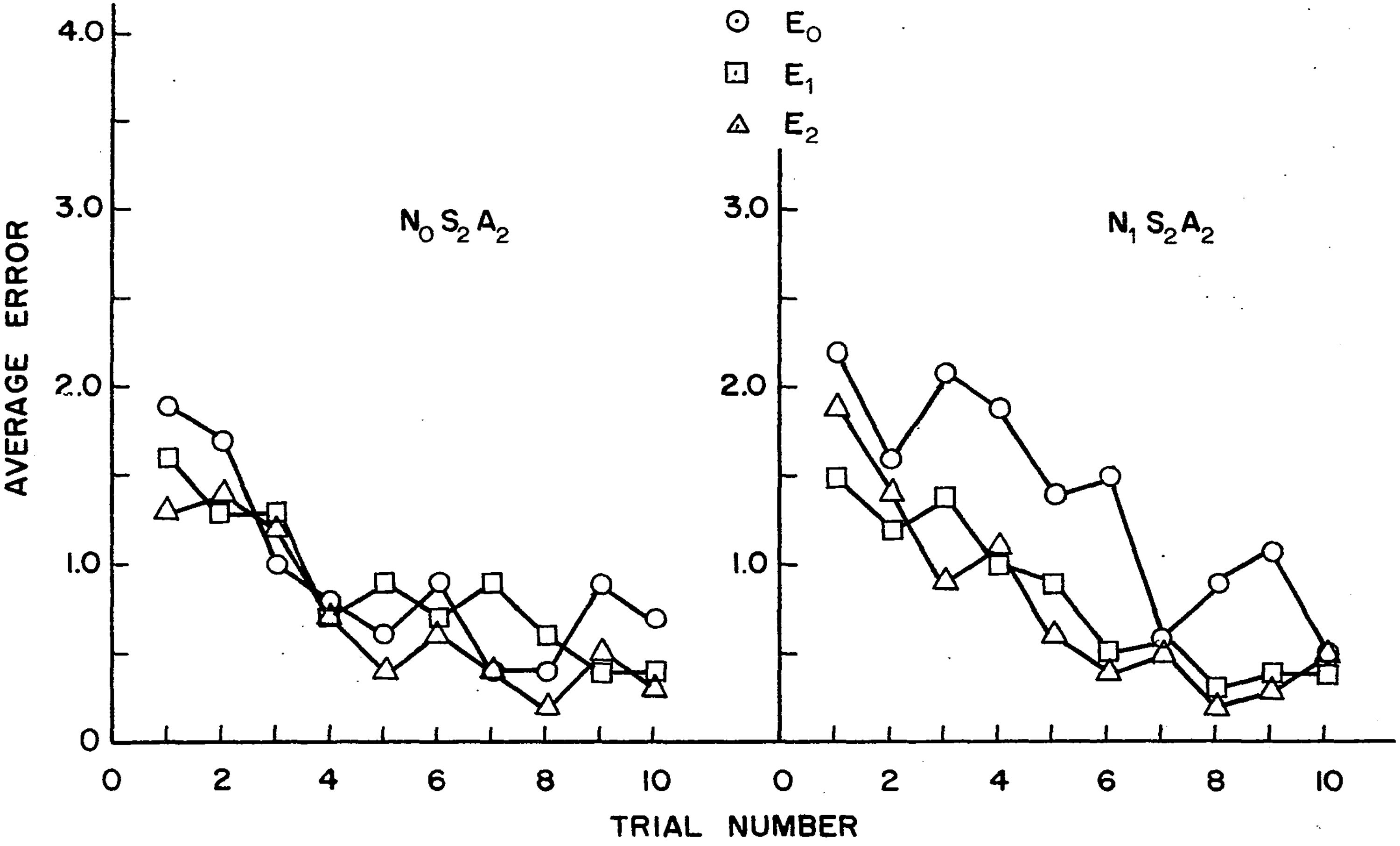


FIGURE 3-13. AVERAGE ERRORS FOR ADULT FEMALES FOR EACH OF THREE LEVELS OF ELECTRIC FIELD INTENSITY UNDER EACH NOISE CONDITION

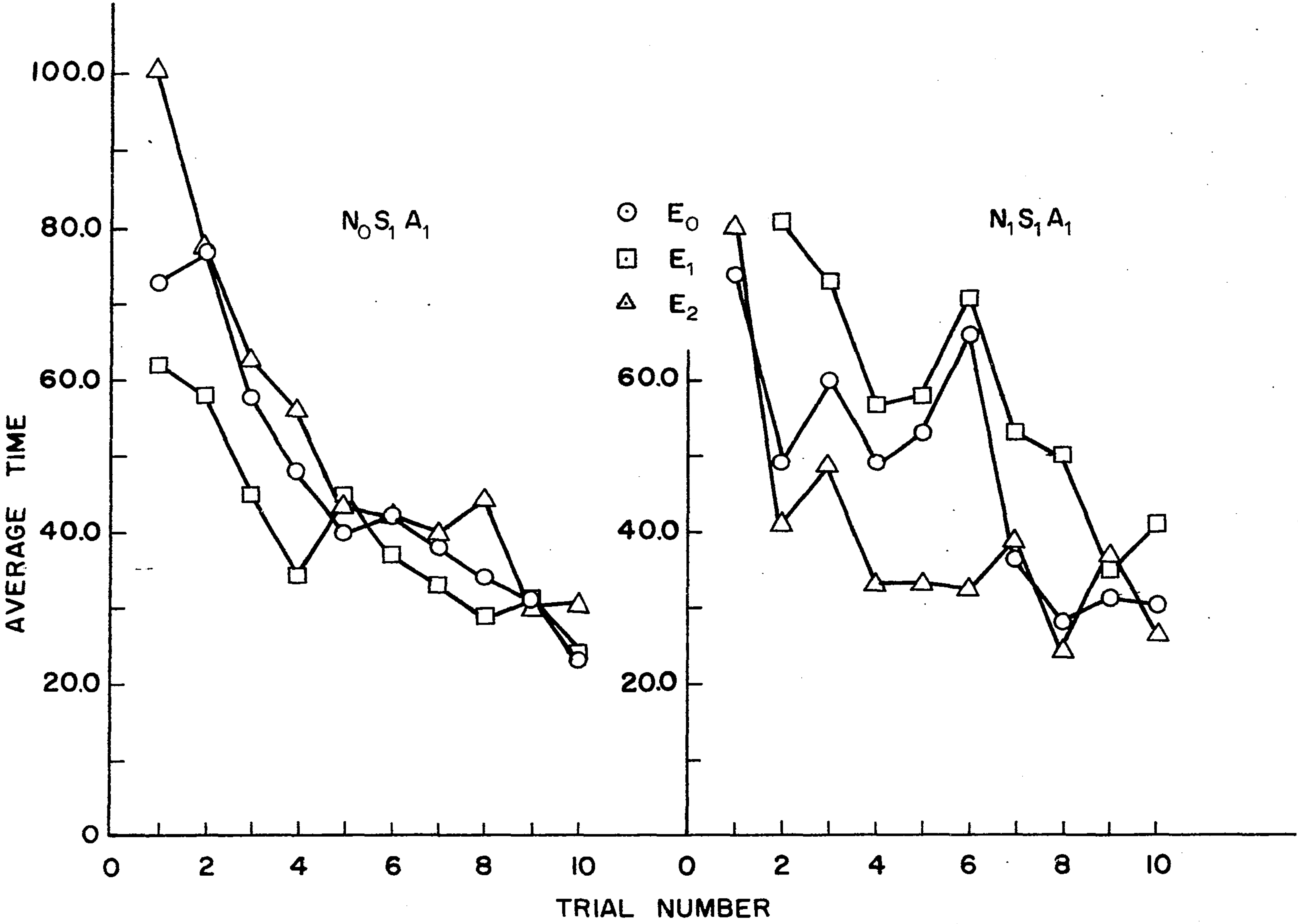


FIGURE 3-14. AVERAGE TIME FOR YOUNG MALES FOR EACH OF THREE LEVELS OF ELECTRIC FIELD INTENSITY UNDER EACH NOISE CONDITION

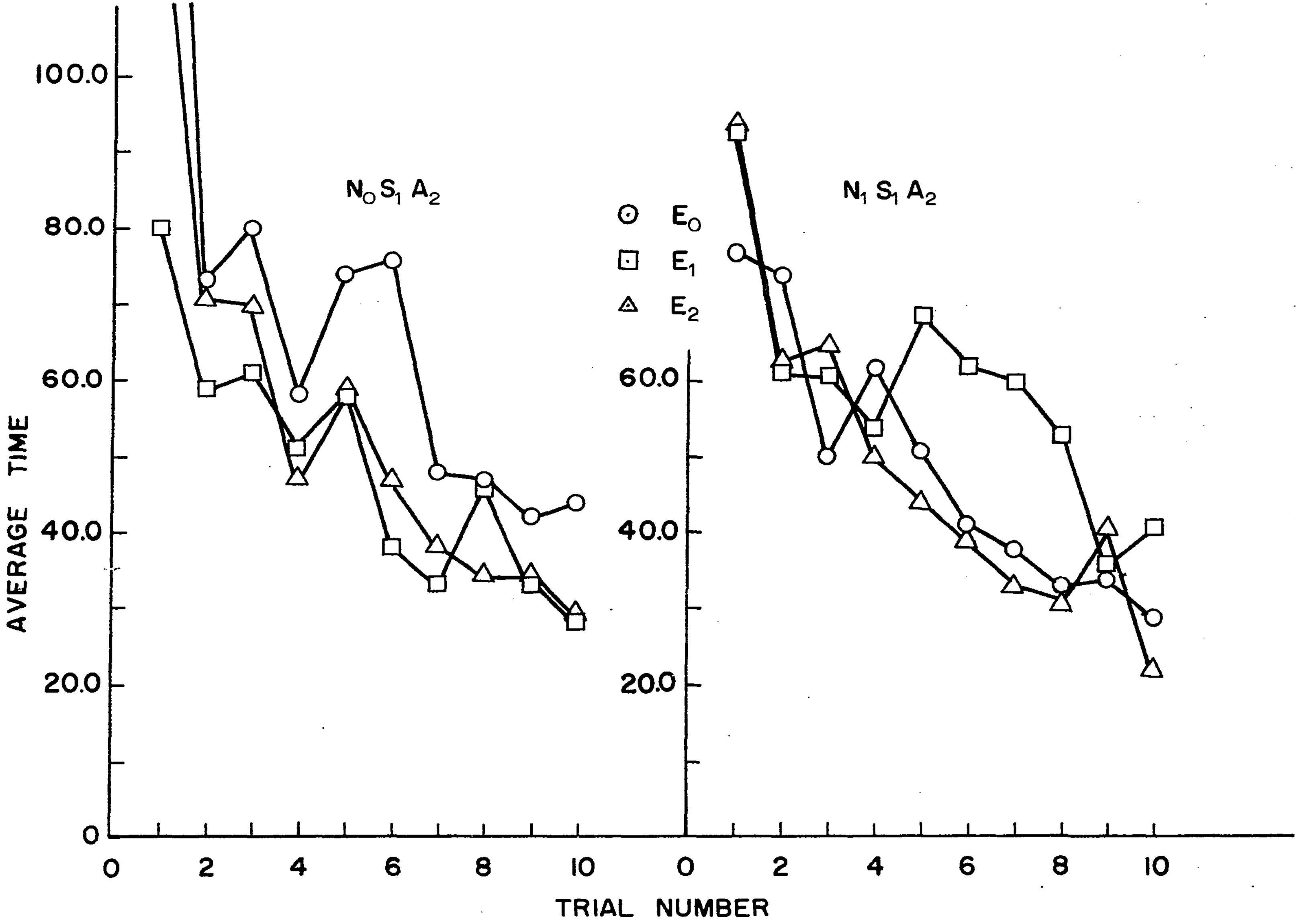


FIGURE 3-15. AVERAGE TIME FOR ADULT MALES FOR EACH OF THREE LEVELS OF ELECTRIC FIELD INTENSITY UNDER EACH NOISE CONDITION

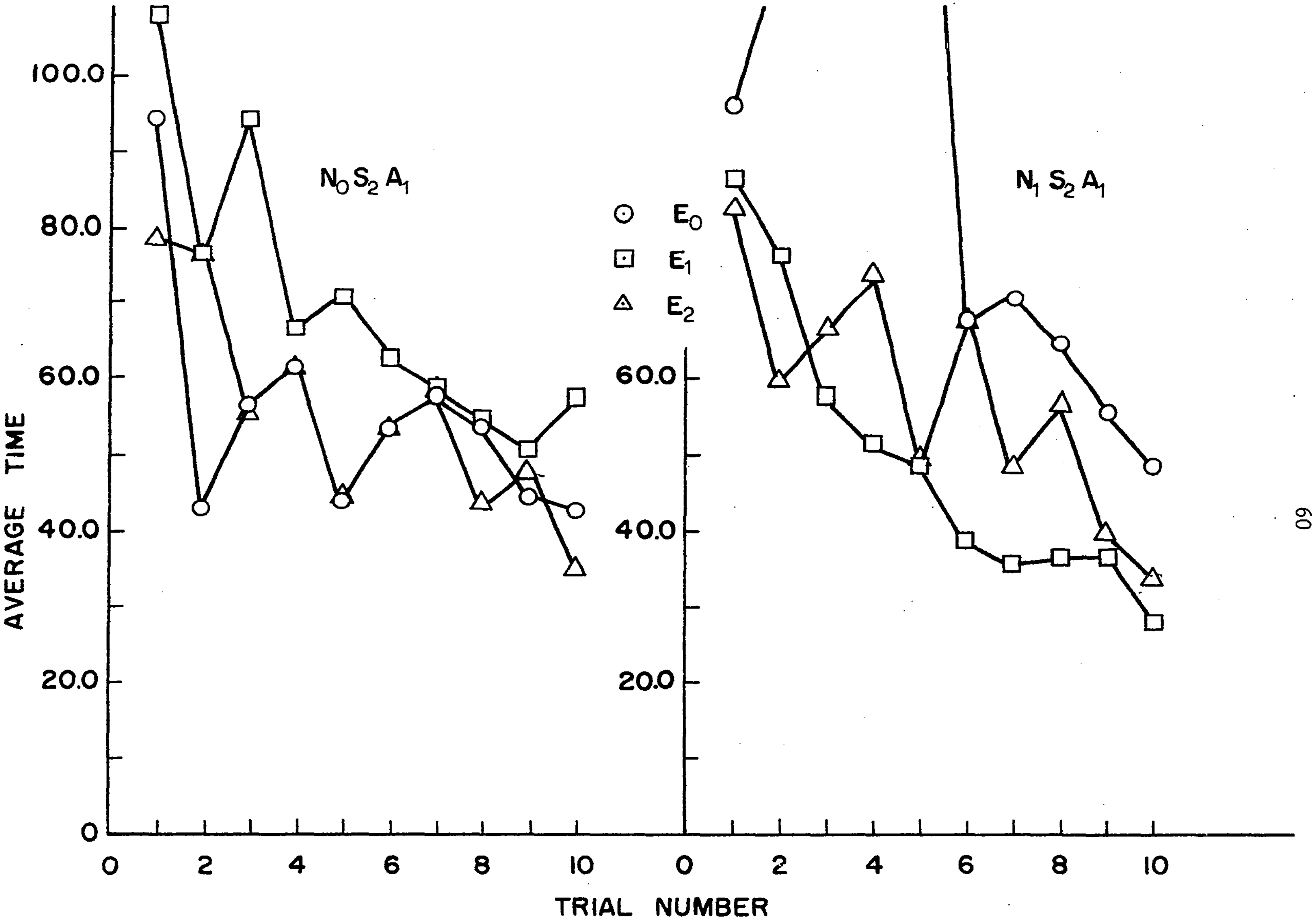


FIGURE 3-16. AVERAGE TIME FOR YOUNG FEMALES FOR EACH OF THREE LEVELS OF ELECTRIC FIELD INTENSITY UNDER EACH NOISE CONDITION

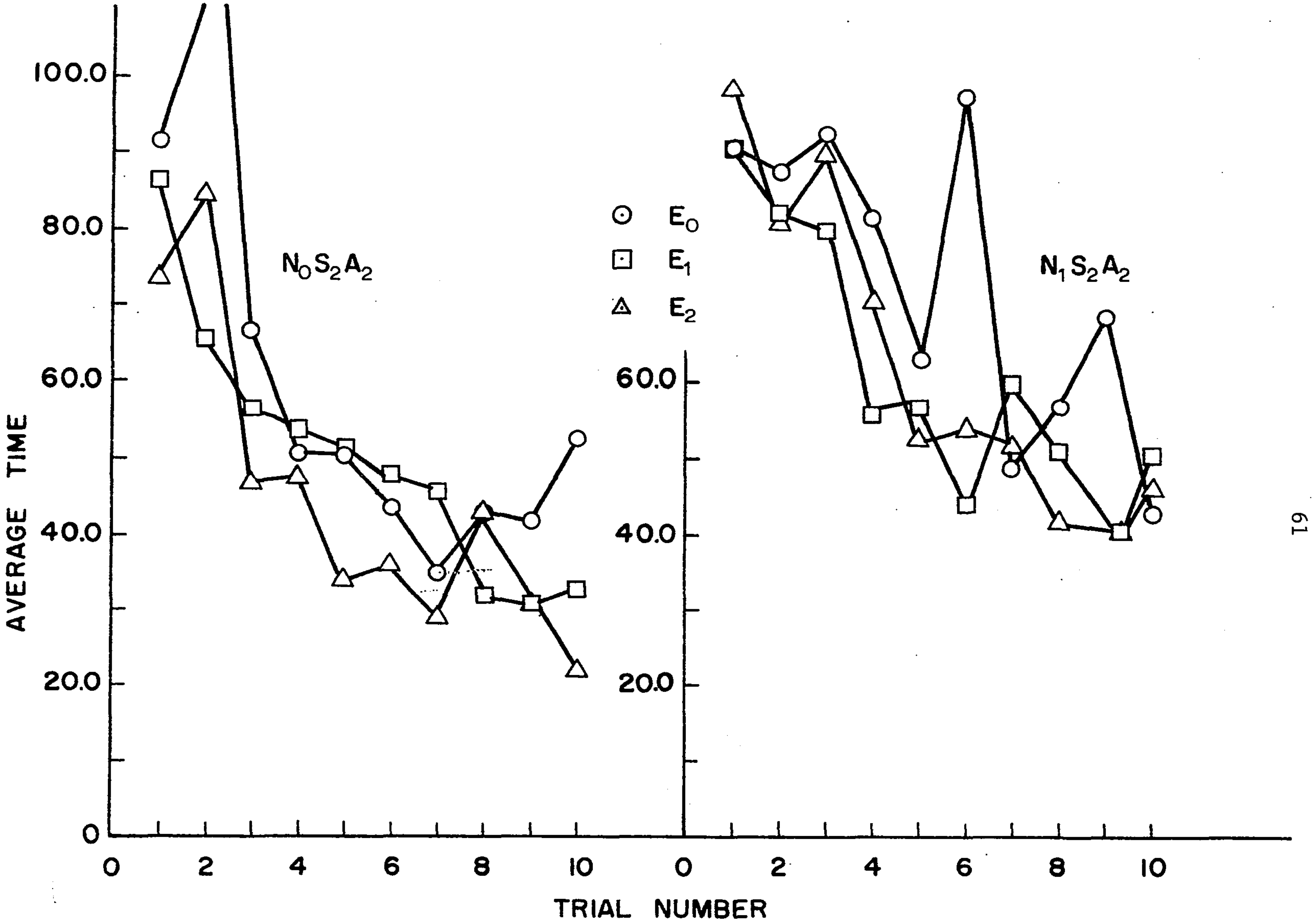


FIGURE 3-17. AVERAGE TIME FOR ADULT FEMALES FOR EACH OF THREE LEVELS OF ELECTRIC FIELD INTENSITY UNDER EACH NOISE CONDITION

CHAPTER IV

DISCUSSION

One of the criteria of a well designed experiment is that maximum information be obtained for the least expenditure of resources. Based on this criterion, this study was planned and a randomized-complete-block design with repeated measures was selected. The advantages of this design, for testing our stated hypotheses (Chapter III) as well as revealing all possible interaction terms that are significant, are obvious (Winer, 1962; Eisenhart, 1947; Cochran, 1947). In cases where significant main effects and significant interaction terms are present, however, the linear additive assumptions of the analysis of variance model do not hold, and a supplementary statistic is required to clarify the significance of the main effects. There are many such supplementary tests available (Duncan, 1955; Tukey, 1949; Dunnett, 1955; Newman, 1939), that would lead to the same conclusion. The test chosen in this study to supplement the ANOVA in cases where significant interaction terms appear along with significant main effects is the Newman-Keuls Method (Newman, 1939). This choice was based mainly on convenience, since the method utilizes the score totals of the treatment (T) cells, which is part of our ANOVA computer program output. It also involves fewer computational steps than any of the other methods. In order to facilitate the choice of cells to be used in the Newman-Keuls' test, tables of cell means are presented (Tables 5, 6, 7, and 8). The cell's total value is then obtained by multiplying the mean value in the table by ten (since ten replicates were used in each cell). Interpretation of the summary Tables 1, 2, 3, and 4 is now given.

Experiment I - Error Scores

The ANOVA summary table (Table 1) shows three significant main effects, ions (I), sex (S), and Age (A), and two significant interaction terms SxA and SxAxN. Two Newman-Keuls tests were run to test the following hypotheses:

1. Treatments are independent of sex (S), $(\tau_{\cdots S_1} = \tau_{\cdots S_2})$.
2. Treatments are independent of age (A), $(\tau_{\cdots A_1} = \tau_{\cdots A_2})$.

One test was run on the following four cells in Table 5: $N_oI_oS_1A_1$. $N_oI_oS_1A_2$, $N_oI_oS_2A_1$, and $N_oI_oS_2A_2$; and one test was run on the following eight cells: $N_oI_oS_1A_1$, $N_oI_oS_1A_2$, $N_oI_oS_2A_1$, $N_oI_oS_2A_2$, $N_1I_oS_1A_1$, $N_1I_oS_1A_2$, $N_1I_oS_2A_1$, and $N_1I_oS_2A_2$. As a result of these tests the hypothesis $\tau_{\cdots A_1} = \tau_{\cdots A_2}$ *could not be rejected* at either the 0.99 or the 0.95 confidence levels. Therefore it is concluded that *age* is *not a significant* factor affecting the error scores of the rats running the maze. The sex hypothesis on the other hand was rejected and therefore sex is a significant main effect along with the ion density variation. The confounded effect of age in this case is due to the multiplicative properties of the interaction terms. In conclusion the following statement is made:

When error scores are used, male rats subjected to negative air ionization, regardless of age or noise, performed significantly better than the female rats subjected to the same conditions.

Experiment I - Time Scores

The ANOVA summary table (Table 2) shows one significant main effect,

TABLE 5. MEANS OF CELLS EXPERIMENT I (ERROR SCORES)

		N_0			N_1		
		I_0	I_1	I_2	I_0	I_1	I_2
S_1	A_1	2.91	3.25	3.31	2.85	3.00	2.95
	A_2	2.97	2.75	3.37	2.93	3.12	3.34
S_2	A_1	2.5	2.44	3.03	2.65	2.91	2.58
	A_2	3.07	3.23	3.09	2.62	3.16	2.99

TABLE 6. MEANS OF CELLS EXPERIMENT I (TIME SCORES)

		N_0			N_1		
		I_0	I_1	I_2	I_0	I_1	I_2
S_1	A_1	46.34	39.39	70.48	53.01	42.21	69.22
	A_2	68.34	59.95	54.51	48.69	55.05	41.79
S_2	A_1	55.47	44.39	63.03	83.77	59.26	47.99
	A_2	65.45	65.29	40.22	73.28	55.60	51.26

TABLE 7. MEANS OF CELLS EXPERIMENT II (ERROR SCORES)

		N_0			N_1		
		E_0	E_1	E_2	E_0	E_1	E_2
S_1	A_1	2.91	3.04	2.84	2.85	2.99	2.80
	A_2	2.97	3.15	3.19	2.93	3.14	3.37
S_2	A_1	2.50	3.04	2.96	2.65	3.10	3.12
	A_2	3.07	3.12	3.23	2.62	3.16	3.22

TABLE 8. MEANS OF CELLS EXPERIMENT II (TIME SCORES)

		N_0			N_1		
		E_0	E_1	E_2	E_0	E_1	E_2
S_1	A_1	46.34	39.18	52.66	47.99	63.39	40.69
	A_2	64.14	47.41	54.84	42.86	58.91	48.22
S_2	A_1	55.47	70.08	55.69	74.19	50.11	60.16
	A_2	60.19	50.99	44.40	60.87	60.95	62.91

ions and three significant interaction terms NxS, IxS and IxA. To eliminate confounding of experimental error and better interpret the results, a Newman-Keuls test was run to test the following hypotheses:

1. Treatments are independent of the ion condition (I), $\tau\ldots_{I_o} = \tau\ldots_{I_1} = \tau\ldots_{I_2}$
2. Treatments are independent of age (A), $(\tau\ldots_{A_1} = \tau\ldots_{A_2})$, the

test was run on the following six cells in Table 6: $N_oI_oS_1A_1$, $N_oI_1S_1A_1$, $N_oI_2S_1A_1$, $N_oI_oS_1A_2$, $N_oI_1S_1A_2$, and $N_oI_2S_1A_2$. As a result of this test the following hypotheses: $\tau\ldots_{I_o} = \tau\ldots_{I_1} = \tau\ldots_{I_2}$ and $\tau\ldots_{A_1} = \tau\ldots_{A_2}$ could not be rejected at either the 0.99 or the 0.95 confidence levels. This then clearly states that neigher age nor the ion condition is a significant main effect as given by the ANOVA summary table. Therefore, the significant interaction term is due mainly to differences in sex. In conclusion the following statement is made:

When time scores are used female rats regardless of age, noise, or the ion density condition, performed significantly better than the male rats under the same conditions.

The results of experiment I (both error and time scores) are summarized by the following statements.

1. Female rats swam significantly faster than male rats regardless of age, noise, or ion density conditions.
2. When subjected to negative air ions male rats showed a significant reduction in error scores regardless of age or the noise condition. Female rats did not.

In other words the negative air ion concentration (which is of main interest here) proved beneficial only in reducing the error scores of the male rats.

Experiment II - Error Scores

The ANOVA summary table (Table 3) shows only two significant main effects, electric fields (E) and age (A), with no significant interaction terms. In this case the interpretation is straightforward and no supplementary tests are necessary. The conclusion here is that: When error scores are used, adult rats subjected to electric fields, regardless of sex or noise, performed significantly better than the young rats subjected to the same conditions.

Experiment II - Time Scores

The ANOVA summary table (Table 4) shows only one significant main effect, electric fields (E) and four significant interaction terms SxA, ExSxN, ExAxN, and SxAxN. Three Newman-Keuls tests were run to test the following hypotheses:

1. Treatments are independent of the electric fields (E), $(\tau..._{E_o} = \tau..._{E_1} = \tau..._{E_2})$
2. Treatments are independent of age (A), $(\tau..._{A_1} = \tau..._{A_2})$
3. Treatments are independent of noise (N), $(\tau..._{N_o} = \tau..._{N_1})$

One test was run of the following four cells in Table 8: $N_oE_oS_1A_1$. $N_oE_oS_1A_2$, $N_oE_oS_2A_1$, and $N_oE_oS_2A_2$; one test was run on the following six cells: $N_oE_oS_1A_1$, $N_oE_1S_1A_1$, $N_oE_2S_1A_1$, $N_1E_oS_1A_1$, $N_1E_1S_1A_1$, and $N_1E_2S_1A_1$; and one test was run on the following three cells: $N_oE_oS_1A_1$, $N_oE_1S_1A_1$, and $N_oE_2S_1A_1$. As a result of these tests the hypotheses: $(\tau..._{E_o} = \tau..._{E_1} = \tau..._{E_2}$ and $\tau..._{N_o} = \tau..._{N_1}$ were rejected at both the 0.99 and the 0.95 confidence levels. The hypothesis $\tau..._{A_1} = \tau..._{A_2}$ could not be rejected at neither the 0.99 or the 0.95 confidence levels. This indicates that the significant main effects are E, N, and S. In conclusion the following statements are made:

When time scores are used rats (males and females, young and adult) subjected to electric fields regardless of noise performed significantly better than rats not subjected to electric fields.

When time scores are used male rats regardless of age performed better than female rats under the noise condition.

When time scores are used male rats subjected to the combined effects of electric fields and noise, regardless of age, performed significantly better than the female rats under the same conditions.

The results of Experiment II (both error and time scores) are summarized by the following statements:

1. Electric fields significantly reduced the error scores of the adult rats regardless of sex or noise.
2. Electric fields significantly reduced the time scores of all rats, males and females, young and adult.
3. Noise significantly increased the time scores of the female rats regardless of age.
4. Male rats subjected to the combined effects of electric fields and noise performed better than female rats under the same conditions, regardless of age.

The main results of this experimental study are challenging in so far as they relate two organismic variables (sex and age) to a standardized learning situation. In the case of our study where the rat is required to swim from the start box of the maze to the goal box, the learning situation involves both physiological and mental processes. These processes are subject to a large variety of external stimuli, mainly chemical and physical.

Chemical stimuli are the result of mass transfer between the organism and its environment. Humans and animals may be thought of as "combustion engines" having a certain intake of chemicals (inspired gases, foods, and drugs), the combustion or chemical reactions of which produce energy in various forms as determined by the metabolic process of each individual organism. The physical stimuli consist largely of radiations, which may be electromagnetic, corpuscular, or acoustic in their nature. In addition to these there are also physical stimuli in the form of mechanical forces such as gravity, mechanical shocks and vibrations. These various chemical and physical stimuli can be a cause of strain and stress to a living system. A living system (organism) depends for its proper functioning (the ability to obtain energy externally to control its expenditure internally) upon a great number of very finely adjusted equilibrium conditions. It possesses countless mechanisms which serve to protect it from excessive and injurious stimuli and which keep the required equilibria in constant proper adjustment. In engineering language, we may think of the living system as an extremely complex circuit involving feedback networks (positive and negative), servomechanisms, amplifiers, delay switches, and storage devices. The functions of all these are continuously variable and under the control of one or more complex computers deriving their information simultaneously from a multitude of physical and chemical analog transducers.

Changes in the external environment (chemical and physical), however, can prove too extreme for the regulatory mechanisms. In such cases, these mechanisms are unable to maintain a constant internal environment, and there results a deterioration in the performance of the sense organs, the central nervous system, and/or the muscles and glands.

It is evident that performance of living systems is dependent to a large extent on the environmental variables; and since performance has been shown to be related to the organismic variables of sex and age, then it is logical to assume that the environmental variables play a definite role, depending on sex and age, on living organisms. Our results clearly show that sex is an important factor when the organism is subjected to a modified environment. Age is similarly important. The implications here are more than mere findings, for environments of the indoors are usually void of negative ions and positive electric fields, and therefore may cause the living organism to lose its ability to perform efficiently, with a probable detrimental effect on alertness and coordination of reflexes (Cristofv, 1967). A number of negative air ionizers, aerosols, and anti-fatigue devices (electrostatic field generators) are already on the market. Although the applications of these commercial devices is not widespread yet, it is within the realm of possibility that the schools of the future, for example, may be equipped with such devices to aid instruction and improve mental performance as well as delay physical fatigue.

Unfortunately there does not exist in the literature any studies similar to ours, where comparisons and verifications could be made. The beneficial effects of negative air ions and positive electric fields have therefore not yet been firmly established, although work in this area is gaining some interest.

It should be noted here that our experiment was a complex one. Too many interactions appeared to be significant, which complicated the interpretation of the statistics. Therefore it is suggested that if similar studies are to be conducted in the future, the number of variables should be reduced to a smaller number so that interaction terms could be avoided and thus permitting accurate interpretation of significant main effects, without the confounding probabilities of experimental error.

Two of our analyses of variance were based on the error scores of the rats (number of wrong or incorrect choices averaged for 10 trials) and two were based on the time scores of the rats (average time scores of 10 trials). From these scoring techniques we were inferring learning or performance. These statistical inferences however, could possibly prove invalid if the data used in the analyses were transformed say to a logarithmic form (Winer, 1962) or multiplied by constant exponential, etc. The choice of an experimental unit or a treatment measure although is arbitrarily chosen has to be a meaningful one and preferably independent of the experimenter judgements, values and biases. It is well realized that this is a rather difficult task and almost impossible to accomplish. During the course of this study however, the feasibility of a new measure was investigated. This measure is based on the negentropy concept as defined in information theory (an exposition of this new measure is given in Appendix D), coupled with a concept of minimum energy expenditure.

CHAPTER V

SUMMARY

In this study experimental animals (rats) were subjected to three environmental conditions: noise, negative air ions and electric fields. Two experiments were conducted; one experiment involving noise and negative air ions and one experiment involving noise and electric fields. Two organismic variables sex and age were considered. The findings of this study are summarized in the following statements:

1. Female rats, regardless of age, noise or ion density, swam significantly faster than male rats.
2. When subjected to negative air ions, male rats showed significantly lower error scores than females, regardless of age, or the noise condition.
3. When subjected to electric fields, adult rats showed significantly lower error scores than young rats, regardless of sex or the noise condition.
4. When subjected to electric fields all rats (males and females, young and adult) showed significantly lower time scores.
5. When subjected to noise, female rats showed significantly higher time scores than male rats, regardless of age.
6. When subjected to the combined effect of electric fields and noise, male rats showed significantly lower time scores than female rats under the same conditions, regardless of age.

In conclusion it may be said that certain important trends have been established which clearly show that negative air ions and electric fields have a significant effect on living organisms depending on sex and age. However, since scientific knowledge based on one experimental study is not enough to establish a natural or physical law or laws, it is hoped that future studies will be conducted where our experiments are replicated so that these findings can be further supported.

REFERENCES

Atkinson, R. C., Bower, G. H., and Crothers, E. J., An Introduction to Mathematical Learning Theory, John Wiley and Sons, Inc., New York (1965).

Atkinson, R. C., "The Use of Models in Experimental Psychology," Synthese, 12:162 (1960).

Audley, R. J., "A Stochastic Model for Individual Choice Behavior," Psychol. Rev., 67:1 (1960).

Baikov, F., Ya, "Tomatoes in an Electric Field," Priroda, 1:39 (1965).

Barron, C. I., and Dreher, J. J., "Effects of Electric Fields and Negative Ion Concentrations on Test Pilots," Aerospace Medicine, 35:20 (1964).

Bauer, F., "Tests for Effects of Ionized Air and Electroconvulsive Shock on Learning and Innate Behavior in Rats," Behavior and Atmospheric Ions, General Electric Corporation, 4 (1959).

Beckett, J. C., "Air Ionization as an Environment Factor," Elec. Eng., 73 (1954). Presented at AIEE Summer and Pacific General Meeting, Los Angeles, California, June 21-25, 1954, Paper No. 54-225, 1.

Bisa, K., Unpublished Summary, 1938. Behavior and Atmospheric Ions, General Electric Corporation, 2 (1959).

Biss-Grafshaft, K., "The Strain Upon the Organism by Electroaerosols and an Increase in Atmospheric Ionization," presented at the Schwebestoff-technischen Arbeitstagung, Mainz, Germany, (Dec. 1954).

Brillouin, Leon, Science and Information Theory, Academic Press, Inc., New York (1962).

Broadbent, D. E., "Noise, Paced Performance and Vigilance Tasks," Brit. J. Psychol. (Gen. Sec.), 44:295 (1953).

Broadbent, D. E., "Some Effects of Noise on Visual Performance," Quart. J. Exp. Psychol., 6:1 (1954).

Broadbent, D. E., "Effects of Noise of High and Low Frequency on Behavior," Ergonomics, 1:21 (1957).

Broadbent, D. E., "Effects of Noise on an 'Intellectual' Task," J. Acoust. Soc. Amer., 30:824 (1958).

Buettner, K. J. K., "Present Knowledge of Correlation Between Weather Changes, Sferics, and Air Electric Space Charges, and Human Health and Behavior," Federal Proceedings, 16:631 (1957).

Busighina, M. V. and Minkh, A. A., "Vliianiie otritsatelno ionizirovannogo vozduhka no Kholodovuiu retseptsiiu Kozhi," Gigiena Sanit., 21:12 (1956).

Cauer, H., Uber den chemismus der Atemluft wahrend der Inhalation, insbensondere der Elektroinhalation," Zschr. Aerosol-Forsch., 4:310 (1955).

Chalmers, J. A., Atmospheric Electricity, Oxford University Press, England (1949).

Chiles, D. W., Fox, R. E., Rush, J. H., and Stilson, D. W., "Effects of Ionized Air on Decision Making and Vigilance Performance," TDR No. MRL-TDR-62-51 (1962).

Chochran, W. G., "Some Consequences When the Assumptions for the Analysis of Variance Are Not Satisfied," Biometrics, 3:22 (1947).

Cole, J. N., Mohr, G. C., Guild, E., and Gierke, H. E. Von, "The Effects of Low Frequency Noise on Man as Related to the Apollo Space Program," AMRL Memorandum B-66 (March 1964).

Covell, W. P., "Cumulative Auditory Effects Resulting from Multiple Exposure to Intense Acoustic Stimulation," TDR No. AMRL-TDR-62-99 (II) (1963).

Cristofv, C., "The Cristofv Anti-Fatigue Device," Enertronics, Inc. press release (1967).

Dahlke, A. E., "Integrated Approach to Analysis of Variance," Mimeographed Paper, University of Oklahoma (1965).

Davis, Joseph B., "Review of Scientific Information on the Effects of Ionized Air on Human Beings and Animals," Aerospace Medicine, 34:35 (January 1963).

Dessauer, F., Zehn Jahre Forschung auf dem physikalisch-medizinischen Grenzgebiet. Leipzig (1931).

Dolgachev, I. P. and Preobrazhenskaia, Electrischeskie potentsiali slizistoi obolochki nosa u chelovieka v norme pathologii, Fiziol. Zhurn., 40:43 (1954).

Dolgachev, I. P., Reaktsiia stizistoi obolochki nosovoi polosti na okhlazhdenie organizma, Fiziol. Zhurn., 38:459 (1952).

Dolgachev, I. P., O reaktsii slizistoi obolochki nosa na lokalnoe okhlazhdenie pri povrezhdeniiakh tsentralnoi nervnoi sistemy, Fiziol. Zhurn., 39:334 (1953).

Duffy, Elizabeth, Activation and Behavior, John Wiley and Sons, Inc., New York (1962).

Dull, B., Wetter und Gesundheit, Dresden, (1941).

Dull, B. and Dull, T., Zusammenhange zwischen Storungen des Erdmagnetismus und Haufungen von Todesallen, Deutsch. Med. Wschr, 61:95 (1935).

Duncan, D. B., "Multiple Range and Multiple F Tests," Biometrics, 11:1 (1955).

Dunnett, C. W., "A Multiple Comparison Procedure for Comparing Several Treatments with a Control," J. Amer. Statist. Assoc., 50:1906 (1955).

Dussert, A., "Contribution a la recherche du mecanisme de echanges respiratoires pulmenaires," Presse. Therm Clim., 96:118 (1959).

Edstrom, G., "Investigations into the Effects of Unipolarly Charged Air on the Surface Temperature," Acta. Med. Scand., 83:523 (1934).

Eisenhart, C., "The Assumptions Underlying the Analysis of Variance," Biometrics, 3:1 (1947).

Eldred, K. M., Gannon, W. J., and Gierke, H. E., von, "Criteria for Short Time Exposure of Personnel to High Intensity Jet Aircraft Noise," WADC TN 55-355 (Sept. 1955).

Engels, A. and Liese, E., Rauminhalationsuntersuchungen mit P^{32} etikettiertem Wiesbadener Kochbrunnen beim Menschen, Arch. physik, Ther., 6:345 (1954).

Erban, L., Sledovani biochemickych a hematologickych zmen pri aplikaci ionisovaneho vzduchu, Czech. Hyg., 3:255 (1958).

Estes, W. K., "A Random Walk Model for Choice Behavior," in K. J. Arrow, S. Karlin, and P. Suppes (eds.), Mathematical Methods in the Social Sciences, Stanford University Press, 265 (1960).

Faibushevich, V. M., Gidroaeroionizatsiia-novyi faktor fizicheskoi terapii i profilaktiki, Voprosy Kurort., 22:55 (1957).

Frey, A. H., Behavior and Atmospheric Ions, General Electric Corporation (1959).

Fuks, N. A., Mekhanika Aerozolei, Moscow (1955).

Goldman, Stanford, Information Theory, Prentice-Hall, Inc., New York (1953).

Herrington, L. P., and Smith, L. L., "The Effects of High Concentrations of Light Negative Atmospheric Ions on the Growth and Activity of the Albino Rat," Journal of Industrial Hygiene, 17:283 (1935).

Hicks, W. Wesley, "Air Ion Generation, Separation, Metering and Physiological Effects," J. Franklin Inst., 261:209 (1956).

Jerison, H. J., "Combined Effects of Noise and Fatigue on a Complex Counting Task," USAF WADC TR55-360, AD 95232 (1955).

Jerison, H. J., "Differential Effects of Noise and Fatigue on Complex Counting Task," USAF WADC TR55-359 AD 110506 (1956).

Jerison, H. J. and Smith, A. K., "Effect of Acoustic Noise on Time Judgment," USAF WADC TR55-358 AD 99641 (1955).

Jerison, H. J., and Wing S., "Effects of Noise on a Complex Vigilance Task," USAF WADC TR57-14 AD 110700 (1957).

Jerison, H. J. and Wallis, R. A., "Experiments on Vigilance II: One-Clock and Three-Clock Monitoring," USAF WADC TR57-206 AD 118171 (1957).

Jordon, J. and Sokoloff, B., "Air Ionization, Age, and Maze Learning of Rats," Journal of Gerontology, 14:344 (1959).

Kahler, K., Biologische Wirkungen der Luftelektrizilat und der Kunstlichen Ionisierung, Naturwiss., 25:92, 110 (1937).

Kornblueh, I. H., "First Congress of I.S.B.B.," Amer. J. Phys. Med., 38:1 (1959).

Knickerbocker, G. G., Kouwenhoven, W. B., and Barnes, H. C., "Exposure of Mice to Strong AC Electric Field - An Experimental Study," IEEE Trans., 86:26 (1967).

Kornblueh, I. H., Pierson, B. M., and Speicher, F. P., "Relief from Pollinosis in Negatively Ionized Rooms," American Jour. of Phys. Med., 37: 18 (1958).

Krueger, A. P., and Smith, R. F., "Parameters of Gaseous Ion Effects on the Mammalian Trachea," Jour. of General Physiology, 42:959 (1959).

Kryter, K. D., "The Effects of Noise on Man. I. Effects of Noise on Behavior," J. Speech Dis. (Monogr. Suppl. 1) (1950).

Kuster, E. and Frieber, W., Die neueren Ergebnisse von Untersuchungen uber Einwirkung kunstlich ionisierter Luft auf den Organismus hoherer Lebewesen, Bioklim. Beiblatt., 8:95 (1941), 9:11, 129 (1942), 10:54, 133 (1943).

La Berge, D. L., "A Recruitment Theory of Simple Behavior," Psychometrika, 27:375 (1962).

Landsmann, E., Uber die Behandlung von Bronchialasthma mit Aeroionisation, Wien. Klin. Wschr., 48:1384 (1935).

Lazarus, R. S., Deese, J., and Osler, S. F., "The Effects of Psychological Stress Upon Performance," Psychol. Bull., 49:293 (1952).

Mackworth, N. H., "Researches on the Measurement of Human Performance," (Medical Res. Council Rep. No. 268), London: H. M. Stationery Office, (1950).

McGuirk, F. C. J., "Psychological Effects of Artificially Produced Air Ions," Amer. Jour. of Physical Med., 38:136 (1959).

Milsum, J. H., Biological Control Systems Analysis, McGraw-Hill Book Co., New York (1966).

Minehart, J. R., David, T. A., McGurk, F. J., and Kornblueh, I. H., "The Effect of Artificially Ionized Air on Post-Operative Discomfort," Amer. J. Phys. Med., 40:56 (1961).

Minkh, A. A., "The Present Day Concept of the Physiologic and Hygienic Significance of Air Ionization," Excerpta Medica, 3:522 (1957).

Moos, Walter S., "A Preliminary Report on the Effects of Electric Fields on Mice," Aerospace Medicine, 35:374 (April 1964).

Morgan, C. T., Cook, J. S., Chapanis, A., and Lund, M. W., Human Engineering Guide to Equipment Design, McGraw-Hill Book Co., Inc. (1963).

Muller, G., Uber einen luftelektrischen Faktor der Zivilisationspathogenese, Zahnarztliche Welt, 10:241 (1955).

Newman, D., "The Distribution of Range in Samples From a Normal Population, Expressed in Terms of an Independent Estimate of Standard Deviation," Biometrika, 31:20 (1939).

Nielsen, C., and Harper, H., "Effects of Air Ions on Succinoxidase Activity of the Rat Adrenal Gland," Society of Experimental Biology and Medicine, 86:753 (1954).

Piccardi, G., "Astrophysical Phenomena and Terrestrial Events," Translation by I. Fraser, University of Illinois, and by Louise L. Wilson, Foundation for the Study of Cycles (1966).

Raisbeck, Gordon, Information Theory, An Introduction for Scientists and Engineers, MIT Press, Cambridge, Massachusetts (1964).

Reiter, R., "Relationships Between Atmospheric Electric Phenomena and Simultaneous Meteorological Conditions," Final Report, I and II, AF, 052-55 (1960).

Rheinstein, J., "The Influence of Artificially Generated Atmospheric Ions on the Simple Reaction Time and on the Optical Moment," Institute for Technical Electronics, Munich, Germany (Sept. 1960).

Rohrer, E., Einige Ergebnisse einein halbjahriger Luftelektrischbioklimatischer Untersuchungen, Arch. physik. Ther., 3:216 (1951).

Schaeffer, K., "Airborne Condensation Droplets, Ions May Be Mahor Health Factors," Heating, Piping, and Air Conditioning, 31:101 (1959).

Schorer, G., Uber biologische Wirkungen ionisierter Luft, Schweiz. Med. Wschr., 82:350 (1952).

Silverman, D. and Kornblueh, I. H., "Effect of Artificial Ionization of the Air on the Electroencephalogram," Amer. J. Phys. Med., 36:352 (1957).

Slote, L., "Atmospheric Ionization and Human Performance," Unpublished Summary (1962).

Sommer, H. C. and Gierke, H. E., von, "Hearing Sensations in Electric Fields," Aerospace Medicine, 35:834 (Sept. 1964).

Spence, K. W., "Conceptual Models of Spatial and Non-Spatial Selective Learning," in K. W. Spence (ed.), Behavior Theory and Learning, Prentice-Hall, Englewood Cliffs, New Jersey (1960).

Stanley, L., Unpublished Report, 1952, cited in Behavior and Atmospheric Ions, General Electric Corporation, 12 (1959).

Steel, R. G. D. and Torrie, J. H., Principles and Procedures of Statistics, McGraw-Hill Book Company, Inc., New York (1960).

Stein, C., "A Two-Sample Test for a Hypothesis Whose Power Is Independent of the Variance," Ann. Math. Stat., 16:243 (1945).

Strasburger, J. and Lampert, H., Weitere Klinisch-therapeutische Erfahrungen bei der Einatmung negativ ionisierter Luft, Deutsch. Med. Wschr., 59:1316 (1933).

Tchijevsky, A. L., Recherche sur le facteur electrique de l'air atmospherique, maintenant le vie des animaux, Academia Colombiana de ciencias exactas fisicas y naturales Bogota, 4, N. 13-16, 182-194 (1940).

Tchijevsky, A. L., Die Wege des Eindringens von Luftionen in den Organismus und die physiologische Wirkung von Luftionen, Acta. Med. Scand., 83:219 (1934).

Tolman, E. C., "Prediction of Vicarious Trial-and -Error by Means of the Schematic Sow-Bug," Psychol. Rev., 46:318 (1939).

Tukey, J. W., "One Degree of Freedom for Nonadditivity," Biometrics, 51: 232 (1949).

Vail, I. S., and Ivanov, V. V., O vliianii unipoliarno i bipolarno ionizirovannogo vozdukha na zdorovykh liudei, Voprosy Kurort., 25:230 (1960).

Vasiliev, L. L., Teoriia i Praktika Lecheniia Ionizirovannym Vozdukhom, Leningrad (1951).

Vytchikova, M. A., and Minkh, A. A., "On the Use of Aeroionization in the Practice of Athletic Medicine," Physic. Culture and Sport (USSR), 1959, 22:1 *(Manuscript), cited in Behavior and Atmospheric Ions, General* Electric Corporation, 3 (1959).

Washburn, M. F., The Animal Mind, The Macmillan Company, New York, 3rd edition (1926).

Winer, B. J., Statistical Principles in Experimental Design, McGraw-Hill Book Company (1962).

Winsor, T., and Beckett, J., "Biological Effects of Ionized Air in Man," Amer. J. of Phys. Med., 37:83 (1958).

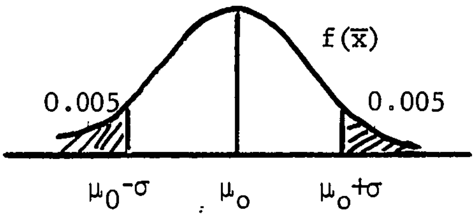
Wofford, J. C., "Effects of Negative Ionization of the Atmosphere on Discriminative Reaction Time, Manipulative Dexterity and Attitudes," Unpublished doctoral dissertation, Baylor University (1962).

Yaglou, C. J., Benjamin, L. C., and Brandt, A., "The Influence of Respiration and Transpiration on Ionic Content of Air of Occupied Rooms," J. of Industrial Hygiene, 15:8 (1933).

APPENDIX A

APPENDIX A

STATISTICAL DETERMINATION OF SAMPLE SIZE FOR INDIVIDUAL CELLS



H_o: $\mu = \mu_o$

H_1: $\mu \neq \mu_o$

In determining a sample size the experimenter is faced with the following three questions:

1. How large a shift in a parameter does one wish to detect?
2. How much variability is present in the population? and
3. What size risks is one willing to take?

Furthermore, it should be realized that the objective of a well designed experiment is to obtain more information for less cost than can be obtained by traditional experimentation. Based on the above criteria the size used in this study was obtained as follows:

The probability statement we wish to make is the following: We would like the absolute value of the difference between the sample mean and the population mean to be less than one standard deviation (standard deviation of experimental error) ninety nine percent of the time. In mathematical notation the above statement is written as

$$P_r \left\{ |(\bar{x} - \mu_o)| < \sigma \right\} = 0.99 \qquad (2)$$

or removing the absolute value sign

$$P_r \left\{ -\sigma < (\bar{x} - \mu_o) < \sigma \right\} = 0.99 \qquad (3)$$

dividing by $\sigma/\sqrt{n}$ for normalizing the distribution we obtain:

$$P_r\left\{-\sqrt{n} < \frac{\overline{x} - \mu_o}{\sigma/\sqrt{n}} < \sqrt{n}\right\} = 0.99 \qquad (4)$$

by the central limit theorem

$$\frac{\overline{x} - \mu_o}{\sigma/\sqrt{n}} \approx Z(0,1) \qquad (5)$$

and from equation (3) the implication is that

$$\sqrt{n} = Z_{0.995} = 2.58 \qquad (6)$$

or

$$n = 7 \qquad (7)$$

It is obvious then, that the use of 10 rats per cell (Figures 2-1 and 2-2) as our sample size is conservative. The sample size obtained by equation (7) could also be verified by various other techniques (Stein, 1945; Steel and Torrie, 1960).

Power of the Test. If $\overline{x}$ is such that $(\mu_o - \sigma) < \overline{x} < (\mu_o + \sigma)$ (Where μ_o is the true mean behavior for that particular group of rats under that particular combination of effects and a sample of size 7 guarantees that 99% of the time $\overline{x}$ will not differ from μ_o by more than σ) then, we accept the hypothesis that $\mu = \mu_o$ at the 99% confidence level. Now to check the power of these rejection numbers for our sample of size 10, suppose that H_1: $\mu = \mu_o + \sigma$ is true. Then the probability that $\overline{x}$ will be less than $(\mu_o + \sigma)$ given H_1 is true is calculated as follows:

$$P_r\left\{\overline{x} < (\mu_o + \sigma)/\mu = (\mu_o + \sigma)\right\} =$$

$$P_r\left\{\overline{x} - (\mu_o + \sigma) < 0\right\} =$$

$$P_r\left\{\frac{\overline{x} - (\mu_o + \sigma)}{\sigma/\sqrt{10}} < 0\right\} = 0.5 \qquad (8)$$

Where we assume no change in the standard deviation. The power is low in this case. If, however, μ changes from μ_o to $(\mu_o + 2\sigma)$ the power computed as in equation (8) is nearly 100%.

It should be stated here that the limitations imposed by both factors of funds and time have rendered the use of a larger sample prohibitive. (If one wishes to guarantee that $|(\overline{x} - \mu_o)| < \frac{\sigma}{10}$ ninety nine percent of the time for example, a sample of size 260 rats is required for each cell, or a total of 10,400 rats for the complete study.)

APPENDIX B

APPENDIX B

INTEGRATED ANALYSIS OF VARIANCE

Introduction

A disk-stored system of 30 independent routines accomplishes a full-model analysis of variance. A summary table identifies the source of each interaction, sums of square, df, mean squares, error term index and F ratios. Intermediate output includes an EMS matrix, sums and means of combination of cells, and term values.

The system requires all zero order interactions, (factors must be listed as fixed or random with nesting orders established), a card identifying factors as fixed or random, and score cards with factor indices. The routine types a message and halts at the conclusion of each analysis allowing operator action in seeking another job.

The system follows the "Integrated Approach to Analysis of Variance", Arnold E. Dahlke, University of Oklahoma (1966).

Treating replications as a factor in the analysis, up to a seven-way analysis of variance can be executed with any arrangement of nesting factors and fixed/random factors. If an eighth factor is nested in all other factors, the user may process an eight-way analysis of variance.

All routines require disk-storage with appropriate dimension and equivalence table entries. The system uses 974 sectors for permanent storage with main links in core images and subprograms in system output format. The Diskss link requires the maximum incore storage of 19,995 cores; the Diskss links may use a maximum of 4368 work sectors. The system was originally written for the 20K-1620 IBM computer. However, the version used here has been adapted for the IBM 360 which now is being utilized at the University.

On the following pages are presented the working details of the computer program together with brief discussions of the various subroutines. This is followed by a Fortran IV listing of the program.

INPUT CARD FORMATS

All fields are right-justified unless otherwise indicated.

Problem Specification Card (DFINPT link)

Cols.	Information
1- 4	Number of factors in the analysis
5- 8	Left-justified alphameric name of factor one
9-12	Number of levels in factor one: negative if nested factor
13-16	Left-justified alphameric name of factor two
17-20	Number of levels in factor two: negative if nested factor
21-24	Left-justified alphameric name of factor three
25-28	Number of levels in factor three: negative if nested factor
29-32	Left-justified alphameric name of factor four
33-36	Number of levels in factor four: negative if nested factor
37-40	Left-justified alphameric name of factor five
41-44	Number of levels in factor five: negative if nested factor
45-48	Left-justified alphameric name of factor six
49-52	Number of levels in factor six: negative if nested factor
53-56	Left-justified alphameric name of factor seven

Cols.	Information
57-60	Number of levels in factor seven: negative if nested factor
61-64	Left-justified alphameric name of factor eight
65-68	Number of levels of factor eight: negative if nested factor
69-72	Must contain alphameric blanks
73-80	Not used; may contain user identification data

Note: All fields beyond column 20 are optional.

Continuation Cards (DFINPT link)

Cols.	Information
1- 4	Number of nesting factors to be read from this card
5- 8	Negative index of first nesting factor
9-12	Negative index of second nesting factor, if any
13-16	Negative index of third nesting factor, if any
17-20	Negative index of fourth nesting factor, if any
21-24	Negative index of fifth nesting factor, if any
25-28	Negative index of sixth nesting factor, if any
29-32	Negative index of seventh nesting factor, if any
33-80	Not used; may contain user identification data

Fixed Random Indentification Cards (EMS link)

Cols.	Information
1- 4	Zero if factor one is fixed; one if factor one is random
5- 8	Zero if factor two is fixed; one if factor two is random
9-12	Zero if factor three is fixed; one if factor three is random
13-16	Zero if factor four is fixed; one if factor four is random
17-20	Zero if factor five is fixed; one if factor five is random

Cols.	Information
21-24	Zero if factor six is fixed; one if factor six is random
25-28	Zero if factor seven is fixed; one if factor seven is random
29-32	Zero if factor eight is fixed; one if factor eight is random
33-80	Not used; may contain user identification data
	Note: All fields beyond column 8 are optional.

Score Cards (INPT link)

Cols.	Information
1-12	SCORE in FORMAT (F12.0); decimal, if punched, overrides specification
13-16	Factor one index
17-20	Factor two index
21-24	Factor three index, if any
25-28	Factor four index, if any
29-32	Factor five index, if any
33-36	Factor six index, if any
37-40	Factor seven index, if any
41-44	Factor eight index, if any
45-80	Not used; may contain user identification data

DESCRIPTION OF ROUTINES

The *Zero Order Degrees of Freedom Input* program (DFINPT) reads from the Problem Specification card the number of factors (NFCTRS), then alternately an alphameric name element (ANAME(J)) and the number of levels associated with that element (LEVELS(J)), in FORMAT (I4,8(A4, I4), A4). The routine reads all fields, even if blank, for the purpose of placing flags used in later links. *Columns 69-72 of the first card must contain* alphameric blanks to insure proper operation of the Output link.

Available storage limits the number of factors to seven unless an eighth factor is nested within all seven other factors. A negative element in LEVELS (J) indicates to the routine that the j^{th} zero order interaction contains nesting factors. Scanning from left to right on the first card, a negative LEVELS (J) causes the routine to read another card in FORMAT (8I4) specifying the number of nesting factors (K) and then K negative indicies referencing the nesting factors (K). These indices (assigned when the alphameric names were read) correspond to the position of each name on the first card; indices begin with one. Note that Continuation Cards do not identify the nested factor; therefore Continuation Cards must be stacked in the sequence called for from the negative LEVELS (J) on the first card.

Whenever nesting factors appear, a branch to the Degrees of Freedom Function subprogram (KDF) evaluates the numerical df. For unnested interactions, the df equal LEVELS (J) - 1.

This routine calls the PARTIN link upon completion.

The Partitioning program (PARTIN) unfolds a full model analysis of variance in accordance with rules set forth by Dr. A. E. Dahlke in "Integrated approach to Analysis of Variance", University of Oklahoma, 1966. A matrix of indices (referencing alphameric factor names read in DFINPT) represents each df expression. In PARTIN, nesting factors have negative indices; positive indices appear otherwise. Upon completion of each higher order interaction expression, a branch to the Degrees of Freedom Function subprogram (KDF) evaluates the numberical df.

The alphameric names, the levels of each factor, and the length of each df interaction matrix are moved to the disk working sector at the conclusion of the partitioning process. The routine then calls the EMS link.

The Expected Mean Squares program (EMS) reads a card in FORMAT (8I4) specifying factors as fixed or random. A zero or blank punch indicates a fixed factor; a one in the field identifies each random factor. These fields appear in the same sequence as the names on the Problem Spedification Card in DFINPT.

The routine develops coefficients for the effects of treatment parameters in the full model. If a parametric combination appears in the expected value of a mean square, the coefficient becomes a one; otherwise the program specifies a zero coefficient. Following construction of the matrix, and its intermediate disk storage, the routine determines the appropriate error term for each mean square, if one exists. Immediately following each selection, the typewriter lists the indices of numerator and denominator mean squares together with the coefficients of the treatment parameters (they are also punched as output). These coefficients, in conjunction with the interactions in the summary table, may be used to write the parameters for any expected mean square. For convenience, the row of coefficients contains a blank after each tenth entry. In a row, coefficients run from right to left. A multi-row format is provided if the matrices are more than fifty elements in length.

The routine moves the error term indices (IERROR(J)) to the working sector and calls the INSTRN link.

The Instruction program (INSTRN) symbolically expands the df expressions produced in the DFINPT and PARTIN links, yielding a matrix (INSTRN (J)) of algebraically signed term indices. A symbol table (TSYMBL(J)) and a matrix (ITERM(J) in core) stored on a disk sector corresponding to the symbol table index describe each term. A symbol identifies factors summed over after squaring in a computational routine. For each complete ITERM(J) matrix, the routine generates a SYMBOL and searches the TSYMBL(J) by brute force for its value. If located, the existing index is used in the INSTRN(J) matrix; otherwise, a new entry is made in TSYMBL(J) and the routine moves the current (ITERM(J)) matrix to working sector. Upon completion, each INSTRN(J) matrix occupies a unique disk storage area.

After defining instruction for all interactions, the program sequentially lists the in-core symbol table, five symbols per line without indices. The routine then calls the INPT link.

The Data Input program (INPT) reads in FORMAT (F12.0, 8I4) one SCORE per card together with its associated subscripts. The subscript order must agree with the order given for the alphameric names in DFINPT. One or two function subprograms (INDEX or JNDEX) assigns a storage location to the SCORE. With 193 or fewer scores the INDEX subprogram collapses the NFCTRS subscripts into a single value and stores the score as an element of I(J) in core. With 194 or more, SCORE becomes the j^{th} element of a temporary in-core matrix, where j is equal to the last index on the score card. After reading the greatest level of the last factor, the JNDEX subprogram collapses the remaining indices into a single value and the temporary matrix is moved to a disk sector corresponding to the value. With disk-stored data the input must be stacked in order such that the last subscript increases most rapidly. Any other sequence may cause mis-assignment and consequent faulty referencing of data during the computational subprograms.

The most economical operation with disk-stored data follows when the user names replications or subjects as the last factor on the Problem Specification Card.

The routine calls either SUMSQS or DISKSS, depending on the quantity of data specified by the user.

In-Core Sums of Squares program (SUMSQS) uses eight LOCAL subprograms (DOT0 through DOT7) to evaluate each term referenced the ITERM(J) matrix on disk storage, so no term need be evaluated more than once. The DOTn subprograms print or punch the sum, number of scores per sum, mean, and indices of various combinations of cells. The heading identifies factors summed over before squaring in the subprogram, and the routine punches or prints corresponding subscripts at their maximum level, other indices punch or print at their current value.

A running tally generates the value for an interaction's sums of squares. When the corresponding term index is positive, the routine adds the returned value from the appropriate DOTn subprogram to the sum cell; when negative, the returned value is subtracted. The final sums of squares (SUMSQS) replaces the INSTRN(J) matrix on the disk.

The routine calls the MEANSQ link.

The Disk-Storage Sums of Squares program (DISKSS), like its in-core counterpart, utilizes eight LOCAL subroutines (DDOT0 through DDOT7) to evaluate terms. Intermediate output from DDOTn routines follows the same format as DOTn output. However, evaluation of sums of squares follows a slightly different pattern: two sum cells are utilized (SUMSQP for positive and SUMSQN for negative term values) in an attempt to minimize the effects of roundoff error. With large problems, however, it remains the user's responsibility to determine the numerical damage of runoff error in the computational routines provided.

The program calls the MEANSQ link.

The _Mean Squares and F Test_ program (MEANSQ) retrieves from the disk and prints or punches the term values with an index corresponding to each TSYMBL(J) entry. Following evaluation of the mean squares, the routine conducts specified _F_ tests and scores each output line on the disk. The program calls the OUTPT link.

The _Output_ program (OUTPT) provides a summary table of all prior computations. The routine identifies the source of each interaction by printing alphameric factor names. Nesting factors, if any, appear to the left of a four-character blank field (originally input as ANAME(J)); other factor names appear to the right of the blank field. The indices before each alphameric line correspond to the EMS indices and to the error term indices in the summary table. Sums of Squares, _df_, and mean squares are retrieved from the disk and printed for each interaction, followed by the error term index, _df_ and _F_ ratio.

```
      DIMENSION JDUMMY(3),INTRN(8)                                      DFI40010
      DIMENSION KDUMMY(18),LEVELS(8)                                    DFI40020
      DIMENSION LONG1(127),LDUMMY(13)                                   DFI40030
      DIMENSION DF(127),ANAME(9)                                        DFI40040
      COMMON IRECRD,ISECTR,IDUMMY,J,K,NFCTRS,JDUMMY,INTRN,KDUMMY        DFI50010
      COMMON LEVELS,LONG1,LDUMMY,DF,ANAME                               DFI50020
  111 READ (1,1,END=140) NFCTRS, (ANAME(J), LEVELS(J), J=1,8),ANAME(9)
      DO 108 IRECRD=1,NFCTRS                                            DFI70040
      ISECTR=27+IRECRD                                                  DFI70050
      IF (LEVELS(IRECRD))103,101,102                                    DFI70060
  101 STOP 00001                                                        DFI70070
  102 DF(IRECRD)=LEVELS(IRECRD)-1                                       DFI70080
      INTRN(1)=IRECRD                                                   DFI70090
      WRITE (4'ISECTR,3) INTRN(1)
      LONG1(IRECRD)=1                                                   DFI70100
      GO TO 108                                                         DFI70110
  103 READ (1,2)K,(INTRN(J),J=1,K)                                      DFI70120
      IF (INTRN(1))107,104,105                                          DFI70130
  104 STOP 00000                                                        DFI70140
  105 CONTINUE                                                          DFI70150
      DO 106 J=1,K                                                      DFI70160
  106 INTRN(J)=-INTRN(J)                                                DFI70170
  107 LEVELS(IRECRD)=-LEVELS(IRECRD)                                    DFI70180
      K=K+1                                                             DFI70190
      INTRN(K)=IRECRD                                                   DFI70200
      DF(IRECRD)=KDF(K)                                                 DFI70210
      WRITE (4'ISECTR,3) (INTRN(J), J=1,K)
      LONG1(IRECRD)=K                                                   DFI70220
  108 CONTINUE                                                          DFI70230
  110 CALL PARTTN                                                       DFI70240
      GO TO 111
  140 CALL EXIT
    1 FORMAT (I4,8(A4,I4),A4)                                           DFI70010
    2 FORMAT (8I4)                                                      DFI70020
    3 FORMAT(50I5)
      END                                                               DFI70260
```

```
C
C
      SUBROUTINE PARTTN
      DIMENSION ANAME(9),LEVELS(8)                                      PAR40010
      DIMENSION DF(127),INTRN(8)                                        PAR40020
      DIMENSION LONG1(127),IFCTR(8)                                     PAR40030
      DIMENSION ICOMPR(8),LDUMMY(4)                                     PAR40040
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,IIII,JRECRD,INTRN        PAR50010
      COMMON IFCTR,J2,K2,J3,K3,IHOLD,ITEMP,L2,L1,IDUMMY,JDUMMY          PAR50020
      COMMON LEVELS,LONG1,KDUMMY,ICOMPR,LDUMMY,DF,ANAME                 PAR50030
      ITEMP=0                                                           PAR70010
      KOUNT1=NFCTRS                                                     PAR70020
  109 IHOLD=KOUNT1                                                      PAR70030
      DO 159 IRECRD=1,NFCTRS                                            PAR70040
      ISECTR=27+IRECRD                                                  PAR70050
      K=LONG1(IRECRD)                                                   PAR70060
      READ (4'ISECTR,3) (IFCTR(J),J=1,K)
      L2=ITEMP+1                                                        PAR70070
      DO 159 JRECRD=L2,IHOLD                                            PAR70080
      ISECTR=27+JRECRD                                                  PAR70090
      K2=LONG1(JRECRD)                                                  PAR70100
      READ (4'ISECTR,3) (ICOMPR(J),J=1,K2)
      IF (K-1)119,110,119                                               PAR70110
  110 IF (K2-1)113,111,113                                              PAR70120
  111 IF (IFCTR(1)-ICOMPR(1))112,159,112                                PAR70130
  112 INTRN(1)=IFCTR(1)                                                 PAR70140
      INTRN(2)=ICOMPR(1)                                                PAR70150
      L1=2                                                              PAR70160
      GO TO 150                                                         PAR70170
  113 J2=0                                                              PAR70180
  114 DO 116 I=1,K2                                                     PAR70190
      IF(IFCTR(1)-IABS(ICOMPR(I)))115,170,115
  170 IF (J2)171,159,171                                                PAR70210
  171 K=K2                                                              PAR70220
      DO 172 I=1,K                                                      PAR70230
  172 IFCTR(I)=ICOMPR(I)                                                PAR70240
```

```
      GO TO 159                                                         PAR70250
  115 INTRN(I)=ICOMPR(I)                                                PAR70260
  116 CONTINUE                                                          PAR70270
      L1=K2+1                                                           PAR70280
      INTRN(L1)=IFCTR(1)                                                PAR70290
      IF (J2)117,150,117                                                PAR70300
  117 K=K2                                                              PAR70310
      DO 118 I=1,K                                                      PAR70320
  118 IFCTR(I)=ICOMPR(I)                                                PAR70330
      GO TO 150                                                         PAR70340
  119 IF (K2-1)122,120,122                                              PAR70350
  120 K2=K                                                              PAR70360
      K=1                                                               PAR70370
      K3=ICOMPR(1)
      DO 121 I=1,K2                                                     PAR70390
  121 ICOMPR(I)=IFCTR(I)                                                PAR70400
      IFCTR(1)=K3                                                       PAR70410
      J2=1                                                              PAR70420
      GO TO 114                                                         PAR70430
  122 IF (ICOMPR(1))128,123,124                                         PAR70440
  123 STOP 00003                                                        PAR70450
  124 DO 125 I=1,K                                                      PAR70460
      DO 125 J=1,K2                                                     PAR70470
      IF (ICOMPR(J)-IABS(IFCTR(I))) 125,159,125
  125 CONTINUE                                                          PAR70490
      DO 126 I=1,K                                                      PAR70500
  126 INTRN(I)=IFCTR(I)                                                 PAR70510
      DO 127 I=1,K2                                                     PAR70520
      J=I+K                                                             PAR70530
  127 INTRN(J)=ICOMPR(I)                                                PAR70540
      L1=K+K2                                                           PAR70550
      GO TO 150                                                         PAR70560
  128 DO 132 I=1,K                                                      PAR70570
      IF (IFCTR(I))132,129,130                                          PAR70580
  129 STOP 00004                                                        PAR70590
  130 DO 131 J=1,K2                                                     PAR70600
```

```
      IF (IFCTR(I)-IABS(ICOMPR(J))) 131,159,131
  131 CONTINUE                                                          PAR70620
  132 CONTINUE                                                          PAR70630
      DO 138 I=1,K2                                                     PAR70640
      IF (ICOMPR(I))138,133,134                                         PAR70650
  133 STOP 00005                                                        PAR70660
  134 DO 137 J=1,K                                                      PAR70670
      IF (IFCTR(J))136,135,138                                          PAR70680
  135 STOP 00006                                                        PAR70690
  136 IF (ICOMPR(I)+IFCTR(J))137,159,137                                PAR70700
  137 CONTINUE                                                          PAR70710
      STOP 00007                                                        PAR70720
  138 CONTINUE                                                          PAR70730
      K3=0                                                              PAR70740
      DO 146 I=1,K                                                      PAR70750
      IF (IFCTR(I))140,139,147                                          PAR70760
  139 STOP 00008                                                        PAR70770
  140 INTRN(I)=IFCTR(I)                                                 PAR70780
      K3=I                                                              PAR70790
      DO 145 J=1,K2                                                     PAR70800
      IF (ICOMPR(J))142,141,146                                         PAR70810
  141 STOP 00009                                                        PAR70820
  142 IF (IFCTR(I)-ICOMPR(J))145,143,145                                PAR70830
  143 K2=K2-1                                                           PAR70840
      DO 144 J2=J,K2                                                    PAR70850
      J3=J2+1                                                           PAR70860
  144 ICOMPR(J2)=ICOMPR(J3)                                             PAR70870
      GO TO 146                                                         PAR70880
  145 CONTINUE                                                          PAR70890
      STOP 00010                                                        PAR70900
  146 CONTINUE                                                          PAR70910
      STOP 00011                                                        PAR70920
  147 J=K3                                                              PAR70930
      DO 148 I=1,K2                                                     PAR70940
      J=J+1                                                             PAR70950
  148 INTRN(J)=ICOMPR(I)                                                PAR70960
```

```
      L1=K3+K2                                                          PAR70970
      J3=K3+1                                                           PAR70980
      DO 149 I=J3,K                                                     PAR70990
      L1=L1+1                                                           PAR71000
  149 INTRN(L1)=IFCTR(I)                                                PAR71010
  150 K2=KOUNT1                                                         PAR71020
      KOUNT1=KOUNT1+1                                                   PAR71030
      DO 154 I=IHOLD,K2                                                 PAR71040
      IF (LONG1(I)-L1)154,151,154                                       PAR71050
  151 ISECTR=27+I                                                       PAR71060
      READ (4'ISECTR,3) (ICOMPR(J),J=1,L1)
      DO 153 J=1,L1                                                     PAR71070
      DO 152 K3=1,L1                                                    PAR71080
      IF (ICOMPR(J)-INTRN(K3))152,153,152                               PAR71090
  152 CONTINUE                                                          PAR71100
      GO TO 154                                                         PAR71110
  153 CONTINUE                                                          PAR71120
      KOUNT1=K2                                                         PAR71130
      GO TO 159                                                         PAR71140
  154 CONTINUE                                                          PAR71150
      ISECTR=27+KOUNT1                                                  PAR71160
      DF(KOUNT1)=KDF(L1)                                                PAR71170
      WRITE (4'ISECTR,3) (INTRN(J), J=1,L1)
      LONG1(KOUNT1)=L1                                                  PAR71180
  159 CONTINUE                                                          PAR71190
      IF (IHOLD-KOUNT1)160,161,160                                      PAR71200
  160 ITEMP=IHOLD                                                       PAR71210
      GO TO 109                                                         PAR71220
  161 ISECTR=1                                                          PAR71230
      WRITE(4'ISECTR,4) (ANAME(J),J=1,9)
      ISECTR=2
      WRITE (4'ISECTR,3) (LEVELS(J), J=1,NFCTRS)
      ISECTR=3
      WRITE (4'ISECTR,3) (LONG1(J),J=1,KOUNT1)
      ISECTR=15
      WRITE (4'ISECTR,6) (DF(J),J=1,KOUNT1)
```

```
  163 CALL EMS                                                          PAR71250
99999 RETURN                                                            PAR71260
    3 FORMAT(50I5)
    4 FORMAT(60A4)
    6 FORMAT(40F5.0)
      END                                                               PAR71270
C
C
      SUBROUTINE EMS
      DIMENSION IRANDM(8),LONG1(127)                                    EMS40010
      DIMENSION IFCTR(8),ICOMPR(8)                                      EMS40020
      DIMENSION IEMS(127),JEMS(127)                                     EMS40030
      DIMENSION IERROR(127)                                             EMS40040
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,KOUNT3,JRECRD            EMS50010
      COMMON IRANDM,IFCTR,J2,K2,KOUNT2,IDUMMY,JDUMMY,KDUMMY,L2          EMS50020
      COMMON LDUMMY,L3,L4,ICOMPR,LONG1,IERROR,IEMS,JEMS                 EMS50030
      READ (1,2)(IRANDM(J),J=1,NFCTRS)                                  EMS70040
      KOUNT2=KOUNT1+22                                                  EMS70050
      DO 213 IRECRD=1,KOUNT1                                            EMS70060
      ISECTR=27+IRECRD                                                  EMS70070
      K=LONG1(IRECRD)                                                   EMS70080
      READ (4'ISECTR,5) (IFCTR(J), J=1,K)
      DO 212 JRECRD=1,KOUNT1                                            EMS70090
      ISECTR=27+JRECRD                                                  EMS70100
      K2=LONG1(JRECRD)                                                  EMS70110
      J2=KOUNT1+1-JRECRD                                                EMS70120
      IF (K2-K)211,200,200
  200 READ (4'ISECTR,5) (ICOMPR(J), J=1,K2)
      DO 206 I=1,K                                                      EMS70140
      DO 201 L2=1,K2                                                    EMS70150
      IF(IABS(IFCTR(I))-IABS(ICOMPR(L2)))201,202,201
  201 CONTINUE                                                          EMS70170
      GO TO 211                                                         EMS70180
  202 K2=K2-1                                                           EMS70190
      IF (K2)203,210,204                                                EMS70200
  203 STOP 00013                                                        EMS70210
```

```
204 DO 205 L3=L2,K2                                                     EMS70220
    L4=L3+1                                                             EMS70230
205 ICOMPR(L3)=ICOMPR(L4)                                               EMS70240
206 CONTINUE                                                            EMS70250
    DO 209 I=1,K2                                                       EMS70260
    IF (ICOMPR(I))209,207,208                                           EMS70270
207 STOP 00014                                                          EMS70280
208 L2=ICOMPR(I)                                                        EMS70290
    IF (IRANDM(L2))209,211,209                                          EMS70300
209 CONTINUE                                                            EMS70310
210 IEMS(J2)=1                                                          EMS70320
    GO TO 212                                                           EMS70330
211 IEMS(J2)=0                                                          EMS70340
212 CONTINUE                                                            EMS70350
    KOUNT3=KOUNT2+6*IRECRD                                              EMS70360
    ISECTR=KOUNT3                                                       EMS70370
    WRITE (4'ISECTR,5) (IEMS(J), J=1,KOUNT1)
213 CONTINUE                                                            EMS70380
    K=KOUNT1+1                                                          EMS70390
    WRITE (3,3)
    DO 218 IRECRD=1,KOUNT1                                              EMS70410
    ISECTR=KOUNT2+6*IRECRD                                              EMS70420
    L2=K-IRECRD                                                         EMS70430
    READ (4'ISECTR,5) (IEMS(J), J=1,KOUNT1)
    IEMS(L2)=0                                                          EMS70440
    DO 216 JRECRD=1,KOUNT1                                              EMS70450
    IF (JRECRD-IRECRD)214,216,214                                       EMS70460
214 ISECTR=KOUNT2+6*JRECRD                                              EMS70470
    READ (4'ISECTR,5) (JEMS(J), J=1,KOUNT1)
    DO 215 I=1,KOUNT1                                                   EMS70480
    IF (IEMS(I)-JEMS(I))216,215,216                                     EMS70490
215 CONTINUE                                                            EMS70500
    IERROR(IRECRD)=JRECRD                                               EMS70510
    GO TO 217                                                           EMS70520
216 CONTINUE                                                            EMS70530
    IERROR(IRECRD)=0                                                    EMS70540
```

```
  217 IEMS(L2)=1                                                        EMS70550
      WRITE (3,4)IRECRD,IERROR(IRECRD),(IEMS(J),J=1,KOUNT1)
  218 CONTINUE                                                          EMS70570
      ISECTR=9                                                          EMS70580
      WRITE (4'ISECTR,5) (IERROR(J), J=1,KOUNT1)
  220 CALL INSTRN                                                       EMS70590
99999 RETURN                                                            EMS70600
    2 FORMAT (8I4)
    3 FORMAT (1H1,47X 26HEXPECTED MEAN SQUARE TABLE/1H0, 4H EXP, 2X2HER)
    4 FORMAT (1H0, 2I4, 2X 5(10I2, 2X) / (1H , 10X 5(10I2, 2X)))
    5 FORMAT (50I5)
      END                                                               EMS70610
C
C
      SUBROUTINE INSTRN
      DIMENSION TSYMBL(128),LONG1(127)                                  INS40010
      DIMENSION INTRN(8),ITERM(8)                                       INS40020
      DIMENSION II(8),ITIME(7)                                          INS40030
      DIMENSION IORDER(8),LONG2(128)                                    INS40040
      DIMENSION INSTRX(128),LONG3(127)                                  INS40050
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,KOUNT3,KOUNT4            INS50010
      COMMON INTRN,KOUNT5,ITIME,J2,K2,J3,K3,LENGTH,ITEMP,L2,NSYMBL      INS50020
      COMMON L3,NINST,IORDER,LONG1,NADDED,LONG2,LONG3,ITERM,II          INS50030
      COMMON INSTRX,TSYMBL                                              INS50040
      WRITE (3,14)                                                      INS70030
      KOUNT4=KOUNT3+5                                                   INS70040
      KOUNT5=KOUNT4+KOUNT1                                              INS70050
      TSYMBL(1)=999999.0E0
      NSYMBL=0                                                          INS70070
      DO 337 IRECRD=1,KOUNT1                                            INS70080
      ISECTR=27+IRECRD                                                  INS70090
      DO 301 I=2,8                                                      INS70100
  301 IORDER(I)=9999                                                    INS70110
      NINST=0                                                           INS70120
      K=LONG1(IRECRD)                                                   INS70130
      READ (4'ISECTR,5) (INTRN(J), J=1,K)
```

```
      DO 303 I=1,K                                                      INS70140
      IF (INTRN(I))303,302,304                                          INS70150
  302 STOP 00015                                                        INS70160
  303 ITERM(I)=INTRN(I)                                                 INS70170
      STOP 00016                                                        INS70180
  304 NADDED=0                                                          INS70190
      LASTAD=K-I+1                                                      INS70200
      DO 305 J=2,8                                                      INS70210
  305 II(J)=9999                                                        INS70220
  306 II(1)=I                                                           INS70230
      J=1                                                               INS70240
      IF (NADDED)300,315,307                                            INS70250
  300 STOP 00300                                                        INS70260
  307 DO 308 L2=1,7                                                     INS70270
  308 ITIME(L2)=1                                                       INS70280
  309 K2=II(J)                                                          INS70290
      K3=I+J-1                                                          INS70300
      ITERM(K3)=INTRN(K2)                                               INS70310
      IF (J-NADDED)310,315,310                                          INS70320
  310 IF (J-8)312,311,312                                               INS70330
  311 STOP 00017                                                        INS70340
  312 J=J+1                                                             INS70350
      IF (ITIME(J)-1)314,313,314                                        INS70360
  313 ITIME(J)=ITIME(J)+1                                               INS70370
      L2=J-1                                                            INS70380
      II(J)=II(L2)+1                                                    INS70390
      GO TO 309                                                         INS70400
  314 II(J)=II(J)+1                                                     INS70410
      GO TO 309                                                         INS70420
  315 LENGTH=NADDED+I-1                                                 INS70430
      IF (LENGTH)316,317,318                                            INS70440
  316 STOP 00018                                                        INS70450
  317 SYMBOL=0.0                                                        INS70460
      GO TO 324                                                         INS70470
  318 DO 319 L2=1,LENGTH                                                INS70480
  319 IORDER(L2)=IABS(ITERM(L2))
```

```
      J2=LENGTH-1                                                       INS70500
      DO 322 L2=1,J2                                                    INS70510
      J3=L2+1                                                           INS70520
      DO 322 L3=J3,LENGTH                                               INS70530
      IF (IORDER(L2)-IORDER(L3))322,320,321                             INS70540
  320 STOP 00019                                                        INS70550
  321 ITEMP=IORDER(L2)                                                  INS70560
      IORDER(L2)=IORDER(L3)                                             INS70570
      IORDER(L3)=ITEMP                                                  INS70580
  322 CONTINUE                                                          INS70590
      CONST=0.10                                                        INS70600
      SYMBOL=0.0                                                        INS70610
      DO 323 L2=1,LENGTH                                                INS70620
      CONST=10.0*CONST                                                  INS70630
      ORDER=IORDER(L2)                                                  INS70640
  323 SYMBOL=SYMBOL+ORDER*CONST                                         INS70650
  324 DO 325 L2=1,NSYMBL                                                INS70660
      IF (SYMBOL-TSYMBL(L2))325,326,325                                 INS70670
  325 CONTINUE                                                          INS70680
      NSYMBL=NSYMBL+1                                                   INS70690
      ISECTR=KOUNT4+NSYMBL                                              INS70700
      L2=NSYMBL                                                         INS70710
      TSYMBL(NSYMBL)=SYMBOL                                             INS70720
      LONG2(NSYMBL)=LENGTH                                              INS70730
      WRITE (4'ISECTR,5) (IORDER(J2), J2=1,LENGTH)
  326 NINST=NINST+1                                                     INS70740
      INSTRX(NINST)=L2*((-1)**(LASTAD-NADDED+2))                        INS70750
      IF (NADDED)327,330,327                                            INS70760
  327 L2=7                                                              INS70770
  328 IF (II(L2)-(K-(NADDED-L2)))333,329,335                            INS70780
  329 IF (L2-1)334,330,334                                              INS70790
  330 IF (NADDED-LASTAD)332,336,331                                     INS70800
  331 STOP 00020                                                        INS70810
  332 NADDED=NADDED+1                                                   INS70820
      GO TO 306                                                         INS70830
  333 II(J)=II(J)+1                                                     INS70840
```

```
      GO TO 307                                                         INS70850
  334 J=J-1                                                             INS70860
  335 L2=L2-1                                                           INS70870
      GO TO 328                                                         INS70880
  336 ISECTR=KOUNT5+2*IRECRD                                            INS70890
      LONG3(IRECRD)=NINST                                               INS70900
      WRITE (4'ISECTR,5) (INSTRX(J), J=1,NINST)
  337 CONTINUE                                                          INS70910
      WRITE (3,15) (TSYMBL(J), J=1,NSYMBL)
  339 CALL INPT                                                         INS70930
99999 RETURN                                                            INS70940
    5 FORMAT (50I5)
   14 FORMAT (/////17H TABLE OF SYMBOLS/)
   15 FORMAT (5F16.1)
      END                                                               INS70950
C
C
      SUBROUTINE INPT
      DIMENSION LEVELS(8),X(193)                                        INP40010
      DIMENSION IDUMMY(127),JDUMMY(16)                                  INP40020
      DIMENSION KDUMMY(16),LONG2(128)                                   INP40030
      DIMENSION LONG3(127)                                              INP40040
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,I1,I2
      COMMON I3,I4,I5,I6,I7,I8,KOUNT5,KONST1,KONST2,KONST3,KONST4
      COMMON KONST5,KONST6,KONST7,J2,K2,J3,K3,LENGTH,ITEMP,L2,L1,L3,L4
      COMMON LEVELS,IDUMMY,LDUMMY,LONG2,LONG3,JDUMMY,TOTAL
      COMMON DEN,SUM,SUM2,KDUMMY,KOUNT6,NRECRD,KLONG,X
      ISECTR=2                                                          INP70020
      READ (4'ISECTR,6) (LEVELS(J), J=1,NFCTRS)
      KONST1=LEVELS(1)                                                  INP70030
      IF (NFCTRS-1)400,407,401                                          INP70040
  400 STOP 00021                                                        INP70050
  401 KONST2=LEVELS(2)*KONST1                                           INP70060
      IF (NFCTRS-2)400,407,402                                          INP70070
  402 KONST3=LEVELS(3)*KONST2                                           INP70080
      IF (NFCTRS-3)400,407,403                                          INP70090
```

```
 403 KONST4=LEVELS(4)*KONST3                                             INP70100
     IF (NFCTRS-4)400,407,404                                            INP70110
 404 KONST5=LEVELS(5)*KONST4                                             INP70120
     IF (NFCTRS-5)400,407,405                                            INP70130
 405 KONST6=LEVELS(6)*KONST5                                             INP70140
     IF (NFCTRS-6)400,407,406                                            INP70150
 406 KONST7=LEVELS(7)*KONST6                                             INP70160
 407 N=1                                                                 INP70170
     DO 408 I=1,NFCTRS                                                   INP70180
 408 N=N*LEVELS(I)                                                       INP70190
     XN=N                                                                INP70200
     NROOT=SQRT(XN)
     NREM=N-NROOT*NROOT                                                  INP70220
     J2=NROOT                                                            INP70230
     IF (NREM)409,410,411                                                INP70240
 409 STOP 00022                                                          INP70250
 410 K2=NROOT                                                            INP70260
     GO TO 412                                                           INP70270
 411 K2=NROOT+1                                                          INP70280
 412 TOTAL=0.0                                                           INP70290
     IF (N-193)413,413,414                                               INP70300
 413 ITYPE=0                                                             INP70310
     GO TO 415                                                           INP70320
 414 ITYPE=1                                                             INP70330
     KLONG=LEVELS(NFCTRS)
     NRECRD=(KLONG/10)+1                                                 INP70350
     KOUNT6=KOUNT5+2*KOUNT1+1                                            INP70360
 415 K=1
 416 SUBTOT=0.0                                                          INP70380
     DO 420 I=1,J2                                                       INP70390
     READ (1,5)SCORE,I1,I2,I3,I4,I5,I6,I7,I8                             INP70400
     SUBTOT=SUBTOT+SCORE                                                 INP70410
     IF (ITYPE)417,419,418                                               INP70420
 417 STOP 00023                                                          INP70430
 418 GO TO (4001,4002,4003,4004,4005,4006,4007,4008),NFCTRS              INP70440
4001 J=I1                                                                INP70450
```

```
      GO TO 4009                                                        INP70460
 4002 J=I2                                                              INP70470
      GO TO 4009                                                        INP70480
 4003 J=I3                                                              INP70490
      GO TO 4009                                                        INP70500
 4004 J=I4                                                              INP70510
      GO TO 4009                                                        INP70520
 4005 J=I5                                                              INP70530
      GO TO 4009                                                        INP70540
 4006 J=I6                                                              INP70550
      GO TO 4009                                                        INP70560
 4007 J=I7                                                              INP70570
      GO TO 4009                                                        INP70580
 4008 J=I8                                                              INP70590
 4009 X(J)=SCORE                                                        INP70600
      IF (J-KLONG)420,4011,4010                                         INP70610
 4010 STOP 04010                                                        INP70620
 4011 J=JNDEX(I1)                                                       INP70630
      ISECTR=KOUNT6+J*NRECRD                                            INP70640
      WRITE (4'ISECTR,7) (X(J), J=1,KLONG)
      GO TO 420                                                         INP70650
  419 J=INDEX(I1)                                                       INP70660
      X(J)=SCORE                                                        INP70670
  420 CONTINUE                                                          INP70680
      TOTAL=TOTAL+SUBTOT                                                INP70690
      IF (K-K2)422,425,421                                              INP70700
  421 STOP 00024                                                        INP70710
  422 IF (K-NROOT)424,423,421                                           INP70720
  423 J2=NREM                                                           INP70730
  424 K=K+1                                                             INP70740
      GO TO 416                                                         INP70750
  425 CONTINUE                                                          INP70760
  427 IF (N-193)428,428,429                                             INP70770
  428 CALL SUMSQS                                                       INP70780
      GO TO 99999
  429 CALL DISKSS                                                       INP70790
```

```
99999 RETURN                                                            INP70800
    5 FORMAT (F12.0,8I4)                                                INP70010
    6 FORMAT (50I5)
    7 FORMAT(20F12.5)
      END                                                               INP70810
C
C
      SUBROUTINE DISKSS
      DIMENSION LONG3(127),INSTRX(128)                                  DIS40010
      DIMENSION LONG2(128),ITERM(8)                                     DIS40020
      DIMENSION LEVELS(8),Z(147)                                        DIS40030
      DIMENSION IDUMMY(8)
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,I1,I2
      COMMON I3,I4,I5,I6,I7,I8,KOUNT5,KONST1,KONST2,KONST3,KONST4
      COMMON KONST5,KONST6,KONST7,J2,K2,J3,K3,LENGTH,ITEMP,L2           DIS50030
      COMMON L1,L3,L4,LEVELS,INSTRX,LONG2,LONG3,ITERM,IDUMMY            DIS50040
      COMMON TOTAL,DEN,SUM,SUM2,J1,J4,J5,J6,J7
      COMMON J8,K1,K4,K5,K6,K7,K8,L5,L6,L7,L8,KOUNT6,NRECRD,KLONG       DIS50060
      COMMON SUMSQP,SUMSQN
      COMMON Z                                                          DIS50070
      KLONG=LEVELS(NFCTRS)                                              DIS70010
      NHALF=NFCTRS/2                                                    DIS70020
      DO 536 IRECRD=1,KOUNT1                                            DIS70030
      ISECTR=KOUNT5+2*IRECRD                                            DIS70040
      FIND (4'ISECTR)
      K=LONG3(IRECRD)                                                   DIS70050
      SUMSQP=0.0                                                        DIS70060
      SUMSQN=0.0                                                        DIS70070
      READ (4'ISECTR,6) (INSTRX(J), J=1,K)
      DO 535 I=1,K                                                      DIS70080
      ICOMND= IABS(INSTRX(I))
      ISECTR= KOUNT4+ ICOMND
      FIND (4'ISECTR)
      LENGTH=LONG2(ICOMND)                                              DIS70110
      IF (LENGTH)503,501,508                                            DIS70120
  501 DEN=N                                                             DIS70130
```

```
      SUM2=TOTAL*TOTAL                                                  DIS70140
      LENGTH=1                                                          DIS70150
  502 ISECTR=KOUNT4+ICOMND                                              DIS70160
      FIND (4'ISECTR)
      VALUE=SUM2/DEN                                                    DIS70170
      WRITE (4'ISECTR,7) VALUE
      LONG2(ICOMND)=-LENGTH                                             DIS70180
      GO TO 504                                                         DIS70190
  503 READ (4'ISECTR,7)VALUE
  504 IF (INSTRX(I))506,505,507                                         DIS70200
  505 STOP 00025                                                        DIS70210
  506 SUMSQN=SUMSQN-VALUE                                               DIS70220
      GO TO 535                                                         DIS70230
  507 SUMSQP=SUMSQP+VALUE                                               DIS70240
      GO TO 535                                                         DIS70250
  508 READ (4'ISECTR,6) (ITERM(J),J=1,LENGTH)
      J2=LENGTH                                                         DIS70260
      DO 510 I1=1,NFCTRS                                                DIS70270
      DO 509 I2=1,LENGTH                                                DIS70280
      IF (ITERM(I2)-I1)509,510,509                                      DIS70290
  509 CONTINUE                                                          DIS70300
      J2=J2+1                                                           DIS70310
      ITERM(J2)=I1                                                      DIS70320
  510 CONTINUE                                                          DIS70330
      DO 511 I1=1,NHALF                                                 DIS70340
      I2=NFCTRS-I1+1                                                    DIS70350
      ITEMP=ITERM(I1)                                                   DIS70360
      ITERM(I1)=ITERM(I2)                                               DIS70370
  511 ITERM(I2)=ITEMP                                                   DIS70380
      K2=1                                                              DIS70390
      K3=1                                                              DIS70400
      K4=1                                                              DIS70410
      K5=1                                                              DIS70420
      K6=1                                                              DIS70430
      K7=1                                                              DIS70440
      K8=1                                                              DIS70450
```

```
      J2=1                                                              DIS70460
      J3=1                                                              DIS70470
      J4=1                                                              DIS70480
      J5=1                                                              DIS70490
      J6=1                                                              DIS70500
      J7=1                                                              DIS70510
      J8=1                                                              DIS70520
      GO TO (519,518,517,516,515,514,513,512),NFCTRS                    DIS70530
  512 K8=ITERM(8)                                                       DIS70540
      J8=LEVELS(K8)                                                     DIS70550
  513 K7=ITERM(7)                                                       DIS70560
      J7=LEVELS(K7)                                                     DIS70570
  514 K6=ITERM(6)                                                       DIS70580
      J6=LEVELS(K6)                                                     DIS70590
  515 K5=ITERM(5)                                                       DIS70600
      J5=LEVELS(K5)                                                     DIS70610
  516 K4=ITERM(4)                                                       DIS70620
      J4=LEVELS(K4)                                                     DIS70630
  517 K3=ITERM(3)                                                       DIS70640
      J3=LEVELS(K3)                                                     DIS70650
  518 K2=ITERM(2)                                                       DIS70660
      J2=LEVELS(K2)                                                     DIS70670
  519 K1=ITERM(1)                                                       DIS70680
      J1=LEVELS(K1)                                                     DIS70690
      SUM=0.0                                                           DIS70700
      SUM2=0.0                                                          DIS70710
      LOOP=NFCTRS-LENGTH+1                                              DIS70720
      GO TO (527,528,529,530,531,532,533,534),LOOP                      DIS70730
  527 CALL DDOT0                                                        DIS70740
      GO TO 502                                                         DIS70750
  528 CALL DDOT1                                                        DIS70760
      GO TO 502                                                         DIS70770
  529 CALL DDOT2                                                        DIS70780
      GO TO 502                                                         DIS70790
  530 CALL DDOT3                                                        DIS70800
      GO TO 502                                                         DIS70810
```

```
  531 CALL DDOT4                                                        DIS70820
      GO TO 502                                                         DIS70830
  532 CALL DDOT5                                                        DIS70840
      GO TO 502                                                         DIS70850
  533 CALL DDOT6                                                        DIS70860
      GO TO 502                                                         DIS70870
  534 CALL DDOT7                                                        DIS70880
      GO TO 502                                                         DIS70890
  535 CONTINUE                                                          DIS70900
      ISECTR=KOUNT5+2*IRECRD                                            DIS70910
      SUMSQ=SUMSQP+SUMSQN                                               DIS70920
      WRITE (4'ISECTR,7) SUMSQ
  536 CONTINUE                                                          DIS70930
  538 CALL MEANSQ                                                       DIS70940
  539 K=JNDEX(I1)                                                       DIS70950
99999 RETURN                                                            DIS70960
    6 FORMAT (50I5)
    7 FORMAT( 10F20.5)
      END                                                               DIS70970
C
C
      SUBROUTINE MEANSQ
      DIMENSION IERROR(127),DF(127)                                     MEA40010
      DIMENSION SS(127),AMS(127)                                        MEA40020
      DIMENSION ANAME(9),LONG1(127)                                     MEA40030
      DIMENSION INTRN(8),IDUMMY(9)                                      MEA40040
      DIMENSION JDUMMY(3),KDUMMY(11)                                    MEA40050
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,NEG2,KOUNT4,INTRN        MEA50010
      COMMON KOUNT5,IDUMMY,NEG,JDUMMY,L2,KDUMMY,LONG1,ANAME,IERROR      MEA50020
      COMMON DF,AMS,SS                                                  MEA50030
      WRITE (3,6)
      ISECTR=1                                                          MEA70050
      READ (4'ISECTR,4) (ANAME(J), J=1,9)
      ISECTR=3                                                          MEA70060
      READ (4'ISECTR,3) (LONG1(J), J=1,KOUNT1)
      ISECTR=9                                                          MEA70070
```

```
      READ (4'ISECTR,3) (IERROR(J), J=1,KOUNT1)
      ISECTR=15                                                         MEA70080
      READ (4'ISECTR,5) (DF(J), J=1,KOUNT1)
      DO 601 IRECRD =1,KOUNT1
      ISECTR=KOUNT5+2*IRECRD                                            MEA70100
      READ (4'ISECTR,8) SUMSQ
      SS(IRECRD)=SUMSQ                                                  MEA70110
  601 AMS(IRECRD)=SUMSQ/DF(IRECRD)                                      MEA70120
      J=KOUNT1+1                                                        MEA70130
      ISECTR=KOUNT4+1                                                   MEA70140
      DO 602 IRECRD=1,J                                                 MEA70150
      READ (4'ISECTR,8) VALUE
      WRITE (3,7)VALUE,IRECRD
  602 CONTINUE                                                          MEA70170
      DO 607 IRECRD=1,KOUNT1                                            MEA70180
      ISECTR=KOUNT5+2*IRECRD                                            MEA70190
      L2=IERROR(IRECRD)                                                 MEA70200
      IF (L2)603,604,605                                                MEA70210
  603 STOP 00603                                                        MEA70220
  604 F=0.0                                                             MEA70230
      DFRDMD=0.0                                                        MEA70240
      GO TO 606                                                         MEA70250
  605 F=AMS(IRECRD)/AMS(L2)                                             MEA70260
      DFRDMD=DF(L2)                                                     MEA70270
  606 WRITE (4'ISECTR,8) SS(IRECRD),DF(IRECRD),AMS(IRECRD),L2,DFRDMD,F
  607 CONTINUE                                                          MEA70280
  609 CALL OUTPT                                                        MEA70290
99999 RETURN                                                            MEA70300
    3 FORMAT(50I5)
    4 FORMAT(60A4)
    5 FORMAT(40F5.0)
    6 FORMAT (/17X,10HTERM VALUE,11X,5HINDEX//)                         MEA70010
    7 FORMAT (F30.8,8X,I4)                                              MEA70020
    8 FORMAT(3F20.5,I5,2F20.5)
      END                                                               MEA70310
C
```

3

```
      SUBROUTINE OUTPT
      DIMENSION ANAME(9),LONG1(127),INTRN(8),IDUMMY(3),M(9),KDUMMY(9)
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,KOUNT3,KOUNT4,INTRN
     1,KOUNT5,M,NEG,IDUMMY,L2,JDUMMY,IFIRST,KDUMMY,LONG1,ANAME,F,
     2DFRDMN,DFRDMD,P
      EQUIVALENCE (M1,M(1)),(M2,M(2)),(M3,M(3)),(M4,M(4)),(M5,M(5))
     1,(M6,M(6)),(M7,M(7)),(M8,M(8)),(M9,M(9))
      WRITE (3,8)
      DO 616 IRECRD =1,KOUNT1
      ISECTR=IRECRD + 27
      FIND (4'ISECTR)
      K= LONG1(IRECRD)
      NEG = 0
      READ (4'ISECTR,5) (INTRN(J), J=1,K)
      ISECTR = KOUNT5 + 2*IRECRD
      FIND (4'ISECTR)
      DO 601 I=1,9
  601 M(I)=9
      DO 604 I=1,K
      IF(INTRN(I)) 603,602,605
  602 STOP 00602
  603 NEG =NEG + 1
  604 M(I) = -INTRN(I)
      STOP 00604
  605 IF(NEG) 606,608,607
  606 STOP 606
  607 IFIRST = NEG +1
      GO TO 609
  608 IFIRST = 1
  609 DO 610 I = IFIRST,K
      J= I+1
  610 M(J) =INTRN(I)
  611 WRITE (3,9) IRECRD,ANAME(M1),ANAME(M2),ANAME(M3),ANAME(M4)
     1,ANAME(M5),ANAME(M6),ANAME(M7),ANAME(M8),ANAME(M9)
  612 READ (4'ISECTR,6) SUMSQ,DFRDMN,AMNSQ,L2,DFRDMD,F
```

```
      IF(L2) 613,614,615
  613 STOP 00613
  614 WRITE (3,10) SUMSQ,DFRDMN,AMNSQ
      GO TO 616
  615 WRITE (3,10) SUMSQ,DFRDMN,AMNSQ,L2,DFRDMD,F
  616 CONTINUE
99999 RETURN
    5 FORMAT (50I5)
    6 FORMAT(3F20.5,I5,2F20.5)
    8 FORMAT( 1H1, 50X, 20HANALYSIS OF VARIANCE /1H0, 53X, 13HSUMMARY TA
     1BLE /1H0, 14X,6HSOURCE, 18X, 15HSUMS OF SQUARES, 2X, 2HDF, 7X,
     211HMEAN SQUARE, 3X, 5HERROR, 3X,  2HDF, 9X,7HF RATIO)
    9 FORMAT (1H0, I4, 4X, 9(A4, 1X))
   10 FORMAT (1H ,36X, F14.4, 2X, F5.0, F16.4, 4X,I4, 2X, F5.0,F18.8,
     1F14.8)
      END
C
C
      FUNCTION KDF(K)
      DIMENSION INTRN(8),IDUMMY(18)                                     40010
      DIMENSION LEVELS(8),ADUMMY(192)                                   40020
      COMMON IRECRD,ISECTR,I,J,KDUMMY,NFCTRS,KOUNT1,JDUMMY,JRECRD       50010
      COMMON INTRN,IDUMMY,LEVELS,ADUMMY                                 50020
      KDF=1                                                             70010
      DO 804 I=1,K                                                      70020
      J=INTRN(I)                                                        70030
      IF (J)803,801,802                                                 70040
  801 STOP 00800                                                        70050
  802 KDF=KDF*(LEVELS(J)-1)                                             70060
      GO TO 804                                                         70070
  803 J=-J                                                              70080
      KDF=KDF*LEVELS(J)                                                 70090
  804 CONTINUE                                                          70100
      RETURN                                                            70110
      END                                                               70120
C
```

```
C
      FUNCTION JNDEX(I9)
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,I1,I2
      COMMON I3,I4,I5,I6,I7,I8,KOUNT5,KONST1,KONST2,KONST3,KONST4
      COMMON KONST5,KONST6,KONST7                                       JND50030
      JTEMP=0                                                           JND70010
      KTEMP=NFCTRS-1                                                    JND70020
      GO TO (907,906,905,904,903,902,901),KTEMP                         JND70030
  901 JTEMP=(I7-1)*KONST6                                               JND70040
  902 JTEMP=JTEMP+(I6-1)*KONST5                                         JND70050
  903 JTEMP=JTEMP+(I5-1)*KONST4                                         JND70060
  904 JTEMP=JTEMP+(I4-1)*KONST3                                         JND70070
  905 JTEMP=JTEMP+(I3-1)*KONST2                                         JND70080
  906 JTEMP=JTEMP+(I2-1)*KONST1                                         JND70090
  907 JNDEX=JTEMP+I1                                                    JND70100
      RETURN                                                            JND70110
      END                                                               JND70120
C
C
      SUBROUTINE DDOTO
      DIMENSION II(8),KDUMMY(2)                                         DD040010
      DIMENSION LDUMMY(407),Z(147)                                      DD040020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DD050010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DD050020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DD050030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DD050040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,Z                             DD050050
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DD050060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DD050070
      DEN=1.0                                                           DD070010
      KHOLD=0                                                           DD070020
      DO 1001 L8=1,J8                                                   DD070030
      II(K8)=L8                                                         DD070040
      DO 1001 L7=1,J7                                                   DD070050
      II(K7)=L7                                                         DD070060
      DO 1001 L6=1,J6                                                   DD070070
```

```
      II(K6)=L6                                                         DD070080
      DO 1001 L5=1,J5                                                   DD070090
      II(K5)=L5                                                         DD070100
      DO 1001 L4=1,J4                                                   DD070110
      II(K4)=L4                                                         DD070120
      DO 1001 L3=1,J3                                                   DD070130
      II(K3)=L3                                                         DD070140
      DO 1001 L2=1,J2                                                   DD070150
      II(K2)=L2                                                         DD070160
      DO 1001 L1=1,J1                                                   DD070170
      II(K1)=L1                                                         DD070180
      J=JNDEX(I1)                                                       DD070190
      IF (J-KHOLD)10,11,10                                              DD070200
   10 ISECTR=KOUNT6+J*NRECRD                                            DD070210
      KHOLD=J                                                           DD070220
      READ (4'ISECTR,6) (Z(J),J=1,KLONG)
   11 ILAST=II(NFCTRS)                                                  DD070230
 1001 SUM2=SUM2+Z(ILAST)*Z(ILAST)                                       DD070240
      RETURN                                                            DD070250
    6 FORMAT(20F12.5)
      END                                                               DD070260
C
C
      SUBROUTINE DDOT1
      DIMENSION II(8),KDUMMY(2)                                         DD040010
      DIMENSION LDUMMY(407),Z(147)                                      DD040020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DD050010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DD050020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DD050030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DD050040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,Z                             DD050050
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DD050060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DD050070
      DEN=J1                                                            DD070030
      KHOLD=0                                                           DD070040
      WRITE (3,1100)K1                                                  DD070050
```

```
      DO 1102 L8=1,J8                                                   DD070060
      II(K8)=L8                                                         DD070070
      DO 1102 L7=1,J7                                                   DD070080
      II(K7)=L7                                                         DD070090
      DO 1102 L6=1,J6                                                   DD070100
      II(K6)=L6                                                         DD070110
      DO 1102 L5=1,J5                                                   DD070120
      II(K5)=L5                                                         DD070130
      DO 1102 L4=1,J4                                                   DD070140
      II(K4)=L4                                                         DD070150
      DO 1102 L3=1,J3                                                   DD070160
      II(K3)=L3                                                         DD070170
      DO 1102 L2=1,J2                                                   DD070180
      II(K2)=L2                                                         DD070190
      DO 1101 L1=1,J1                                                   DD070200
      II(K1)=L1                                                         DD070210
      J=JNDEX(II)                                                       DD070220
      IF (J-KHOLD)10,11,10                                              DD070230
   10 ISECTR=KOUNT6+J*NRECRD                                            DD070240
      KHOLD=J                                                           DD070250
      READ (4'ISECTR,6) (Z(J),J=1,KLONG)
   11 ILAST=II(NFCTRS)                                                  DD070260
 1101 SUM=SUM+Z(ILAST)                                                  DD070270
      SUM2=SUM2+SUM*SUM                                                 DD070280
      VALUE=SUM/DEN                                                     DD070290
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                      DD070300
 1102 SUM=0.0                                                           DD070310
      RETURN                                                            DD070320
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DD070010
 1100 FORMAT (/22H SUMMATION OVER FACTOR,I4//)
    6 FORMAT(20F12.5)
      END                                                               DD070330
C
C
      SUBROUTINE DDOT2
      DIMENSION II(8),KDUMMY(2)                                         DD040010
```

```
      DIMENSION LDUMMY(407),Z(147)                                      DD040020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DD050010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DD050020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DD050030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DD050040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,Z                             DD050050
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DD050060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DD050070
      DEN=J1*J2                                                         DD070030
      KHOLD=0                                                           DD070040
      WRITE (3,1200)K2,K1                                               DD070050
      DO 1202 L8=1,J8                                                   DD070060
      II(K8)=L8                                                         DD070070
      DO 1202 L7=1,J7                                                   DD070080
      II(K7)=L7                                                         DD070090
      DO 1202 L6=1,J6                                                   DD070100
      II(K6)=L6                                                         DD070110
      DO 1202 L5=1,J5                                                   DD070120
      II(K5)=L5                                                         DD070130
      DO 1202 L4=1,J4                                                   DD070140
      II(K4)=L4                                                         DD070150
      DO 1202 L3=1,J3                                                   DD070160
      II(K3)=L3                                                         DD070170
      DO 1201 L2=1,J2                                                   DD070180
      II(K2)=L2                                                         DD070190
      DO 1201 L1=1,J1                                                   DD070200
      II(K1)=L1                                                         DD070210
      J=JNDEX(I1)                                                       DD070220
      IF (J-KHOLD)10,11,10                                              DD070230
   10 ISECTR=KOUNT6+J*NRECRD                                            DD070240
      KHOLD=J                                                           DD070250
      READ (4'ISECTR,6) (Z(J),J=1,KLONG)
   11 ILAST=II(NFCTRS)                                                  DD070260
 1201 SUM=SUM+Z(ILAST)                                                  DD070270
      SUM2=SUM2+SUM*SUM                                                 DD070280
      VALUE=SUM/DEN                                                     DD070290
```

```
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                      DD070300
 1202 SUM=0.0                                                           DD070310
      RETURN                                                            DD070320
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DD070010
 1200 FORMAT (/23H SUMMATION OVER FACTORS,2I4//)
    6 FORMAT(20F12.5)
      END                                                               DD070330
C
C
      SUBROUTINE DDOT3
      DIMENSION II(8),KDUMMY(2)                                         DD040010
      DIMENSION LDUMMY(407),Z(147)                                      DD040020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DD050010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DD050020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DD050030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DD050040
      COMMON L6,L7,L8,KCUNT6,NRECRD,KLONG,Z                             DD050050
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DD050060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DD050070
      DEN=J1*J2*J3                                                      DD070030
      KHOLD=0                                                           DD070040
      WRITE (3,1300)K3,K2,K1                                            DD070050
      DO 1302 L8=1,J8                                                   DD070060
      II(K8)=L8                                                         DD070070
      DO 1302 L7=1,J7                                                   DD070080
      II(K7)=L7                                                         DD070090
      DO 1302 L6=1,J6                                                   DD070100
      II(K6)=L6                                                         DD070110
      DO 1302 L5=1,J5                                                   DD070120
      II(K5)=L5                                                         DD070130
      DO 1302 L4=1,J4                                                   DD070140
      II(K4)=L4                                                         DD070150
      DO 1301 L3=1,J3                                                   DD070160
      II(K3)=L3                                                         DD070170
      DO 1301 L2=1,J2                                                   DD070180
      II(K2)=L2                                                         DD070190
```

```
      DO 1301 L1=1,J1                                                   DD070200
      II(K1)=L1                                                         DD070210
      J=JNDEX(I1)                                                       DD070220
      IF (J-KHOLD)10,11,10                                              DD070230
   10 ISECTR=KOUNT6+J*NRECRD                                            DD070240
      KHOLD=J                                                           DD070250
      READ (4'ISECTR,6) (Z(J),J=1,KLONG)
   11 ILAST=II(NFCTRS)                                                  DD070260
 1301 SUM=SUM+Z(ILAST)                                                  DD070270
      SUM2=SUM2+SUM*SUM                                                 DD070280
      VALUE=SUM/DEN                                                     DD070290
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                      DD070300
 1302 SUM=0.0                                                           DD070310
      RETURN                                                            DD070320
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DD070010
 1300 FORMAT (/23H SUMMATION OVER FACTORS,3I4//)
    6 FORMAT(20F12.5)
      END                                                               DD070330
C
C
      SUBROUTINE DDOT4
      DIMENSION II(8),KDUMMY(2)                                         DD040010
      DIMENSION LDUMMY(407),Z(147)                                      DD040020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DD050010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DD050020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DD050030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DD050040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,Z                             DD050050
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DD050060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DD050070
      DEN=J1*J2*J3*J4                                                   DD070030
      KHOLD=0                                                           DD070040
      WRITE (3,1400)K4,K3,K2,K1                                         DD070050
      DO 1402 L8=1,J8                                                   DD070060
      II(K8)=L8                                                         DD070070
      DO 1402 L7=1,J7                                                   DD070080
```

```
      II(K7)=L7                                                         DD070090
      DO 1402 L6=1,J6                                                   DD070100
      II(K6)=L6                                                         DD070110
      DO 1402 L5=1,J5                                                   DD070120
      II(K5)=L5                                                         DD070130
      DO 1401 L4=1,J4                                                   DD070140
      II(K4)=L4                                                         DD070150
      DO 1401 L3=1,J3                                                   DD070160
      II(K3)=L3                                                         DD070170
      DO 1401 L2=1,J2                                                   DD070180
      II(K2)=L2                                                         DD070190
      DO 1401 L1=1,J1                                                   DD070200
      II(K1)=L1                                                         DD070210
      J=JNDEX(I1)                                                       DD070220
      IF (J-KHOLD)10,11,10                                              DD070230
   10 ISECTR=KOUNT6+J*NRECRD                                            DD070240
      KHOLD=J                                                           DD070250
      READ (4'ISECTR,6) (Z(J),J=1,KLONG)
   11 ILAST=II(NFCTRS)                                                  DD070260
 1401 SUM=SUM+Z(ILAST)                                                  DD070270
      SUM2=SUM2+SUM*SUM                                                 DD070280
      VALUE=SUM/DEN                                                     DD070290
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                      DD070300
 1402 SUM=0.0                                                           DD070310
      RETURN                                                            DD070320
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DD070010
 1400 FORMAT (/23H SUMMATION OVER FACTORS,4I4//)
    6 FORMAT(20F12.5)
      END                                                               DD070330
C
C
      SUBROUTINE DDOT5
      DIMENSION II(8),KDUMMY(2)                                         DD040010
      DIMENSION LDUMMY(407),Z(147)                                      DD040020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DD050010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DD050020
```

```
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN            DD050030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5             DD050040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,Z                              DD050050
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(    DD050060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                               DD050070
      DEN=J1*J2*J3*J4*J5                                                 DD070030
      KHOLD=0                                                            DD070040
      WRITE (3,1500)K5,K4,K3,K2,K1                                       DD070050
      DO 1502 L8=1,J8                                                    DD070060
      II(K8)=L8                                                          DD070070
      DO 1502 L7=1,J7                                                    DD070080
      II(K7)=L7                                                          DD070090
      DO 1502 L6=1,J6                                                    DD070100
      II(K6)=L6                                                          DD070110
      DO 1501 L5=1,J5                                                    DD070120
      II(K5)=L5                                                          DD070130
      DO 1501 L4=1,J4                                                    DD070140
      II(K4)=L4                                                          DD070150
      DO 1501 L3=1,J3                                                    DD070160
      II(K3)=L3                                                          DD070170
      DO 1501 L2=1,J2                                                    DD070180
      II(K2)=L2                                                          DD070190
      DO 1501 L1=1,J1                                                    DD070200
      II(K1)=L1                                                          DD070210
      J=JNDEX(I1)                                                        DD070220
      IF (J-KHOLD)10,11,10                                               DD070230
   10 ISECTR=KOUNT6+J*NRECRD                                             DD070240
      KHOLD=J                                                            DD070250
      READ (4'ISECTR,6) (Z(J),J=1,KLONG)
   11 ILAST=II(NFCTRS)                                                   DD070260
 1501 SUM=SUM+Z(ILAST)                                                   DD070270
      SUM2=SUM2+SUM*SUM                                                  DD070280
      VALUE=SUM/DEN                                                      DD070290
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                       DD070300
 1502 SUM=0.0                                                            DD070310
      RETURN                                                             DD070320
```

```
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DD070010
 1500 FORMAT (/23H SUMMATION OVER FACTORS,5I4//)
    6 FORMAT(20F12.5)
      END                                                               DD070330
C
C
      SUBROUTINE DDOT6
      DIMENSION II(8),KDUMMY(2)                                         DD040010
      DIMENSION LDUMMY(407),Z(147)                                      DD040020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DD050010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DD050020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DD050030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DD050040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,Z                             DD050050
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DD050060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DD050070
      DEN=J1*J2*J3*J4*J5*J6                                             DD070030
      KHOLD=0                                                           DD070040
      WRITE (3,1600)K6,K5,K4,K3,K2,K1                                   DD070050
      DO 1602 L8=1,J8                                                   DD070060
      II(K8)=L8                                                         DD070070
      DO 1602 L7=1,J7                                                   DD070080
      II(K7)=L7                                                         DD070090
      DO 1601 L6=1,J6                                                   DD070100
      II(K6)=L6                                                         DD070110
      DO 1601 L5=1,J5                                                   DD070120
      II(K5)=L5                                                         DD070130
      DO 1601 L4=1,J4                                                   DD070140
      II(K4)=L4                                                         DD070150
      DO 1601 L3=1,J3                                                   DD070160
      II(K3)=L3                                                         DD070170
      DO 1601 L2=1,J2                                                   DD070180
      II(K2)=L2                                                         DD070190
      DO 1601 L1=1,J1                                                   DD070200
      II(K1)=L1                                                         DD070210
      J=JNDEX(I1)                                                       DD070220
```

```
      IF (J-KHOLD)10,11,10                                              DD070230
   10 ISECTR=KOUNT6+J*NRECRD                                            DD070240
      KHOLD=J                                                           DD070250
      READ (4'ISECTR,6) (Z(J),J=1,KLONG)
   11 ILAST=II(NFCTRS)                                                  DD070260
 1601 SUM=SUM+Z(ILAST)                                                  DD070270
      SUM2=SUM2+SUM*SUM                                                 DD070280
      VALUE=SUM/DEN                                                     DD070290
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                      DD070300
 1602 SUM=0.0                                                           DD070310
      RETURN                                                            DD070320
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DD070010
 1600 FORMAT (/23H SUMMATION OVER FACTORS,6I4//)
    6 FORMAT(20F12.5)
      END                                                               DD070330
3
C
      SUBROUTINE DDOT7
      DIMENSION II(8),KDUMMY(2)                                         DD040010
      DIMENSION LDUMMY(407),Z(147)                                      DD040020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DD050010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DD050020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DD050030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DD050040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,Z                             DD050050
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),13),(I4,II(4)),(I5,II(   DD050060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DD050070
      DEN=J1*J2*J3*J4*J5*J6*J7                                          DD070030
      KHOLD=0                                                           DD070040
      WRITE (3,1700)K7,K6,K5,K4,K3,K2,K1                                DD070050
      DO 1702 L8=1,J8                                                   DD070060
      II(K8)=L8                                                         DD070070
      DO 1701 L7=1,J7                                                   DD070080
      II(K7)=L7                                                         DD070090
      DO 1701 L6=1,J6                                                   DD070100
      II(K6)=L6                                                         DD070110
```

```
      DO 1701 L5=1,J5                                                   DD070120
      II(K5)=L5                                                         DD070130
      DO 1701 L4=1,J4                                                   DD070140
      II(K4)=L4                                                         DD070150
      DO 1701 L3=1,J3                                                   DD070160
      II(K3)=L3                                                         DD070170
      DO 1701 L2=1,J2                                                   DD070180
      II(K2)=L2                                                         DD070190
      DO 1701 L1=1,J1                                                   DD070200
      II(K1)=L1                                                         DD070210
      J=JNDEX(I1)                                                       DD070220
      IF (J-KHOLD)10,11,10                                              DD070230
   10 ISECTR=KOUNT6+J*NRECRD                                            DD070240
      KHOLD=J                                                           DD070250
      READ (4'ISECTR,6) (Z(J),J=1,KLONG)
   11 ILAST=II(NFCTRS)                                                  DD070260
 1701 SUM=SUM+Z(ILAST)                                                  DD070270
      SUM2=SUM2+SUM*SUM                                                 DD070280
      VALUE=SUM/DEN                                                     DD070290
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                      DD070300
 1702 SUM=0.0                                                           DD070310
      RETURN                                                            DD070320
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DD070010
 1700 FORMAT (/23H SUMMATION OVER FACTORS,7I4//)
    6 FORMAT(20F12.5)
      END                                                               DD070330
C
C
      SUBROUTINE SUMSQS
      DIMENSION LONG3(127),INSTRX(128)                                  SUM40010
      DIMENSION LONG2(128),ITERM(8)                                     SUM40020
      DIMENSION LEVELS(8),X(193)                                        SUM40030
      DIMENSION IDUMMY(8)                                               SUM40040
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,I1,I2
      COMMON I3,I4,I5,I6,I7,I8,KOUNT5,KONST1,KONST2,KONST3,KONST4
      COMMON KONST5,KONST6,KONST7,J2,K2,J3,K3,LENGTH,ITEMP,L2           SUM50030
```

```
      COMMON L1,L3,L4,LEVELS,INSTRX,LONG2,LONG3,ITERM,IDUMMY           SUM50040
      COMMON TOTAL,DEN,SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6          SUM50050
      COMMON K7,K8,L5,L6,L7,L8,KOUNT6,NRECRD,KLONG,X
      NHALF=NFCTRS/2
      DO 536 IRECRD=1,KOUNT1                                           SUM70020
      ISECTR=KOUNT5+2*IRECRD                                           SUM70030
      K=LONG3(IRECRD)                                                  SUM70040
      SUMSQ=0.0                                                        SUM70050
      READ (4'ISECTR,6) (INSTRX(J), J=1,K)
      DO 535 I=1,K                                                     SUM70060
      ICOMND= IABS(INSTRX(I))
      ISECTR=KOUNT4+ICOMND                                             SUM70080
      LENGTH=LONG2(ICOMND)                                             SUM70090
      IF (LENGTH)503,501,508                                           SUM70100
  501 DEN=N                                                            SUM70110
      SUM2=TOTAL*TOTAL                                                 SUM70120
      LENGTH=1                                                         SUM70130
  502 ISECTR=KOUNT4+ICOMND                                             SUM70140
      VALUE=SUM2/DEN                                                   SUM70150
      WRITE (4'ISECTR,7) VALUE
      LONG2(ICOMND)=-LENGTH                                            SUM70160
      GO TO 504                                                        SUM70170
  503 READ (4'ISECTR,7) VALUE
  504 IF (INSTRX(I))506,505,507                                        SUM70180
  505 STOP 00025                                                       SUM70190
  506 SUMSQ=SUMSQ-VALUE                                                SUM70200
      GO TO 535                                                        SUM70210
  507 SUMSQ=SUMSQ+VALUE                                                SUM70220
      GO TO 535                                                        SUM70230
  508 READ (4'ISECTR,6) (ITERM(J),J=1,LENGTH)
      J2=LENGTH
      DO 510 M1=1,NFCTRS
      DO 509 M2=1,LENGTH
      IF (ITERM(M2)-M1)509,510,509
  509 CONTINUE                                                         SUM70280
      J2=J2+1                                                          SUM70290
```

```
      ITERM(J2)=M1
  510 CONTINUE                                                          SUM70310
      DO 511 M1=1,NHALF
      M2=NFCTRS-M1+1
      ITEMP=ITERM(M1)
      ITERM(M1)=ITERM(M2)
  511 ITERM(M2)=ITEMP
      K2=1                                                              SUM70370
      K3=1                                                              SUM70380
      K4=1                                                              SUM70390
      K5=1                                                              SUM70400
      K6=1                                                              SUM70410
      K7=1                                                              SUM70420
      K8=1                                                              SUM70430
      J2=1                                                              SUM70440
      J3=1                                                              SUM70450
      J4=1                                                              SUM70460
      J5=1                                                              SUM70470
      J6=1                                                              SUM70480
      J7=1                                                              SUM70490
      J8=1                                                              SUM70500
      GO TO (519,518,517,516,515,514,513,512),NFCTRS                    SUM70510
  512 K8=ITERM(8)                                                       SUM70520
      J8=LEVELS(K8)                                                     SUM70530
  513 K7=ITERM(7)                                                       SUM70540
      J7=LEVELS(K7)                                                     SUM70550
  514 K6=ITERM(6)                                                       SUM70560
      J6=LEVELS(K6)                                                     SUM70570
  515 K5=ITERM(5)                                                       SUM70580
      J5=LEVELS(K5)                                                     SUM70590
  516 K4=ITERM(4)                                                       SUM70600
      J4=LEVELS(K4)                                                     SUM70610
  517 K3=ITERM(3)                                                       SUM70620
      J3=LEVELS(K3)                                                     SUM70630
  518 K2=ITERM(2)                                                       SUM70640
      J2=LEVELS(K2)                                                     SUM70650
```

```
  519 K1=ITERM(1)                                                    SUM70660
      J1=LEVELS(K1)                                                  SUM70670
      SUM=0.0                                                        SUM70680
      SUM2=0.0                                                       SUM70690
      LOOP=NFCTRS-LENGTH+1                                           SUM70700
      GO TO (527,528,529,530,531,532,533,534),LOOP                   SUM70710
  527 CALL DOT0                                                      SUM70720
      GO TO 502                                                      SUM70730
  528 CALL DOT1                                                      SUM70740
      GO TO 502                                                      SUM70750
  529 CALL DOT2                                                      SUM70760
      GO TO 502                                                      SUM70770
  530 CALL DOT3                                                      SUM70780
      GO TO 502                                                      SUM70790
  531 CALL DOT4                                                      SUM70800
      GO TO 502                                                      SUM70810
  532 CALL DOT5                                                      SUM70820
      GO TO 502                                                      SUM70830
  533 CALL DOT6                                                      SUM70840
      GO TO 502                                                      SUM70850
  534 CALL DOT7                                                      SUM70860
      GO TO 502                                                      SUM70870
  535 CONTINUE                                                       SUM70880
      ISECTR=KOUNT5+2*IRECRD                                         SUM70890
      WRITE (4'ISECTR,7) SUMSQ
  536 CONTINUE                                                       SUM70900
  538 CALL MEANSQ                                                    SUM70910
  539 K=INDEX(I1)                                                    SUM70920
99999 RETURN                                                         SUM70930
    6 FORMAT (50I5)
    7 FORMAT( 10F20.5)
      END                                                            SUM70940
C
C
      FUNCTION INDEX(I9)
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,I1,I2
```

```
      COMMON I3,I4,I5,I6,I7,I8,KOUNT5,KONST1,KONST2,KONST3,KONST4
      COMMON KONST5,KONST6,KONST7                                       IND50030
      JTEMP=0                                                           IND70010
      GO TO (708,707,706,705,704,703,702,701),NFCTRS                    IND70020
  701 JTEMP=(I8-1)*KONST7                                               IND70030
  702 JTEMP=JTEMP+(I7-1)*KONST6                                         IND70040
  703 JTEMP=JTEMP+(I6-1)*KONST5                                         IND70050
  704 JTEMP=JTEMP+(I5-1)*KONST4                                         IND70060
  705 JTEMP=JTEMP+(I4-1)*KONST3                                         IND70070
  706 JTEMP=JTEMP+(I3-1)*KONST2                                         IND70080
  707 JTEMP=JTEMP+(I2-1)*KONST1                                         IND70090
  708 INDEX=JTEMP+I1                                                    IND70100
      RETURN                                                            IND70110
      END                                                               IND70120
C
C
      SUBROUTINE DOTO
      DIMENSION II(8),KDUMMY(2)                                         DOT40010
      DIMENSION LDUMMY(407),X(193)                                      DOT40020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DOT50010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DOT50020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DOT50030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DOT50040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,X
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DOT50060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DOT50070
      DEN=1.0                                                           DOT70010
      DO 1001 L8=1,J8                                                   DOT70020
      II(K8)=L8                                                         DOT70030
      DO 1001 L7=1,J7                                                   DOT70040
      II(K7)=L7                                                         DOT70050
      DO 1001 L6=1,J6                                                   DOT70060
      II(K6)=L6                                                         DOT70090
      DO 1001 L5=1,J5                                                   DOT70070
      II(K5)=L5                                                         DOT70080
      DO 1001 L4=1,J4                                                   DOT70100
```

```
      II(K4)=L4                                                         DOT70110
      DO 1001 L3=1,J3                                                   DOT70120
      II(K3)=L3                                                         DOT70130
      DO 1001 L2=1,J2                                                   DOT70140
      II(K2)=L2                                                         DOT70150
      DO 1001 L1=1,J1                                                   DOT70160
      II(K1)=L1                                                         DOT70170
      J=INDEX(I1)                                                       DOT70180
 1001 SUM2=SUM2+X(J)*X(J)                                               DOT70190
      RETURN                                                            DOT70200
      END                                                               DOT70210
C
C
      SUBROUTINE DOT1
      DIMENSION II(8),KDUMMY(2)                                         DOT40010
      DIMENSION LDUMMY(407),X(193)                                      DOT40020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DOT50010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DOT50020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DOT50030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DOT50040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,X
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(
     15)),(II(6),I6),(II(7),I7),(II(8),I8)
      DEN=J1                                                            DOT70030
      WRITE (3,1100)K1                                                  DOT70040
      DO 1102 L8=1,J8                                                   DOT70050
      II(K8)=L8                                                         DOT70060
      DO 1102 L7=1,J7                                                   DOT70070
      II(K7)=L7                                                         DOT70080
      DO 1102 L6=1,J6                                                   DOT70090
      II(K6)=L6                                                         DOT70100
      DO 1102 L4=1,J4                                                   DOT70130
      II(K4)=L4                                                         DOT70140
      DO 1102 L3=1,J3                                                   DOT70150
      II(K3)=L3                                                         DOT70160
      DO 1102 L2=1,J2                                                   DOT70170
```

```
      II(K2)=L2                                                         DOT70180
      DO 1101 L1=1,J1                                                   DOT70190
      II(K1)=L1                                                         DOT70200
      J=INDEX(I1)                                                       DOT70210
 1101 SUM=SUM+X(J)                                                      DOT70220
      SUM2=SUM2+SUM*SUM                                                 DOT70230
      VALUE=SUM/DEN                                                     DOT70240
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)
 1102 SUM=0.0                                                           DOT70260
      RETURN                                                            DOT70270
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DOT70010
 1100 FORMAT (/22H SUMMATION OVER FACTOR,I4//)
      END                                                               DOT70280
C
C
      SUBROUTINE DOT2
      DIMENSION II(8),KDUMMY(2)                                         DOT40010
      DIMENSION LDUMMY(407),X(193)                                      DOT40020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DOT50010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DOT50020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DOT50030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DOT50040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,X
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DOT50060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DOT50070
      DEN=J1*J2                                                         DOT70030
      WRITE (3,1200)K2,K1                                               DOT70040
      DO 1202 L8=1,J8                                                   DOT70050
      II(K8)=L8                                                         DOT70060
      DO 1202 L7=1,J7                                                   DOT70070
      II(K7)=L7                                                         DOT70080
      DO 1202 L6=1,J6                                                   DOT70090
      II(K6)=L6                                                         DOT70100
      DO 1202 L5=1,J5                                                   DOT70110
      II(K5)=L5                                                         DOT70120
      DO 1202 L4=1,J4                                                   DOT70130
```

```
      II(K4)=L4                                                         DOT70140
      DO 1202 L3=1,J3                                                   DOT70150
      II(K3)=L3                                                         DOT70160
      DO 1201 L2=1,J2                                                   DOT70170
      II(K2)=L2                                                         DOT70180
      DO 1201 L1=1,J1                                                   DOT70190
      II(K1)=L1                                                         DOT70200
      J=INDEX(I1)                                                       DOT70210
 1201 SUM=SUM+X(J)                                                      DOT70220
      SUM2=SUM2+SUM*SUM                                                 DOT70230
      VALUE=SUM/DEN                                                     DOT70240
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)
 1202 SUM=0.0                                                           DOT70260
      RETURN                                                            DOT70270
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DOT70010
 1200 FORMAT (/23H SUMMATION OVER FACTORS,2I4//)
      END                                                               DOT70280
C
C
      SUBROUTINE DOT3
      DIMENSION II(8),KDUMMY(2)                                         DOT40010
      DIMENSION LDUMMY(407),X(193)                                      DOT40020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DOT50010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DOT50020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DOT50030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DOT50040
      COMMON L6,L7,L8,KCUNT6,NRECRD,KLONG,X
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DOT50060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DOT50070
      DEN=J1*J2*J3                                                      DOT70030
      WRITE (3,1300)K3,K2,K1                                            DOT70040
      DO 1302 L8=1,J8                                                   DOT70050
      II(K8)=L8                                                         DOT70060
      DO 1302 L7=1,J7                                                   DOT70070
      II(K7)=L7                                                         DOT70080
      DO 1302 L6=1,J6                                                   DOT70090
```

```
      II(K6)=L6                                                         DOT70100
      DO 1302 L5=1,J5                                                   DOT70110
      II(K5)=L5                                                         DOT70120
      DO 1302 L4=1,J4                                                   DOT70130
      II(K4)=L4                                                         DOT70140
      DO 1301 L3=1,J3                                                   DOT70150
      II(K3)=L3                                                         DOT70160
      DO 1301 L2=1,J2                                                   DOT70170
      II(K2)=L2                                                         DOT70180
      DO 1301 L1=1,J1                                                   DOT70190
      II(K1)=L1                                                         DOT70200
      J=INDEX(II)                                                       DOT70210
 1301 SUM=SUM+X(J)                                                      DOT70220
      SUM2=SUM2+SUM*SUM                                                 DOT70230
      VALUE=SUM/DEN                                                     DOT70240
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                      DOT70250
 1302 SUM=0.0                                                           DOT70260
      RETURN                                                            DOT70270
   13 FORMAT (F19.8,F10.0,F19.8,8I3)                                    DOT70010
 1300 FORMAT (/23H SUMMATION OVER FACTORS,3I4//)
      END                                                               DOT70280
C
C
      SUBROUTINE DOT4
      DIMENSION II(8),KDUMMY(2)                                         DOT40010
      DIMENSION LDUMMY(407),X(193)                                      DOT40020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DOT50010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DOT50020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DOT50030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DOT50040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,X
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(
     15)),(II(6),I6),(II(7),I7),(II(8),I8)
      DEN=J1*J2*J3*J4                                                   DOT70030
      WRITE (3,1400)K4,K3,K2,K1                                         DOT70040
      DO 1402 L8=1,J8                                                   DOT70050
```

```
      II(K8)=L8                                                         DOT70060
      DO 1402 L7=1,J7                                                   DOT70070
      II(K7)=L7                                                         DOT70080
      DO 1402 L6=1,J6                                                   DOT70090
      II(K6)=L6                                                         DOT70100
      DO 1402 L5=1,J5                                                   DOT70110
      II(K5)=L5                                                         DOT70120
      DO 1401 L4=1,J4                                                   DOT70130
      II(K4)=L4                                                         DOT70140
      DO 1401 L3=1,J3                                                   DOT70150
      II(K3)=L3                                                         DOT70160
      DO 1401 L2=1,J2                                                   DOT70170
      II(K2)=L2                                                         DOT70180
      DO 1401 L1=1,J1                                                   DOT70190
      II(K1)=L1                                                         DOT70200
      J=INDEX(I1)                                                       DOT70210
 1401 SUM=SUM+X(J)                                                      DOT70220
      SUM2=SUM2+SUM*SUM                                                 DOT70230
      VALUE=SUM/DEN                                                     DOT70240
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)
 1402 SUM=0.0                                                           DOT70260
      RETURN                                                            DOT70270
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DOT70010
 1400 FORMAT (/23H SUMMATION OVER FACTORS,4I4//)
      END                                                               DOT70280
C
C
      SUBROUTINE DOT5
      DIMENSION II(8),KDUMMY(2)                                         DOT40010
      DIMENSION LDUMMY(407),X(193)                                      DOT40020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DOT50010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DOT50020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DOT50030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DOT50040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,X
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DOT50060
```

```
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                                DOT50070
      DEN=J1*J2*J3*J4*J5                                                  DOT70030
      WRITE (3,1500)K5,K4,K3,K2,K1                                        DOT70040
      DO 1502 L8=1,J8                                                     DOT70050
      II(K8)=L8                                                           DOT70060
      DO 1502 L7=1,J7                                                     DOT70070
      II(K7)=L7                                                           DOT70080
      DO 1502 L6=1,J6                                                     DOT70090
      II(K6)=L6                                                           DOT70100
      DO 1501 L5=1,J5                                                     DOT70110
      II(K5)=L5                                                           DOT70120
      DO 1501 L4=1,J4                                                     DOT70130
      II(K4)=L4                                                           DOT70140
      DO 1501 L3=1,J3                                                     DOT70150
      II(K3)=L3                                                           DOT70160
      DO 1501 L2=1,J2                                                     DOT70170
      II(K2)=L2                                                           DOT70180
      DO 1501 L1=1,J1                                                     DOT70190
      II(K1)=L1                                                           DOT70200
      J=INDEX(I1)                                                         DOT70210
 1501 SUM=SUM+X(J)                                                        DOT70220
      SUM2=SUM2+SUM*SUM                                                   DOT70230
      VALUE=SUM/DEN                                                       DOT70240
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                        DOT70250
 1502 SUM=0.0                                                             DOT70260
      RETURN                                                              DOT70270
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                      DOT70010
 1500 FORMAT (/23H SUMMATION OVER FACTORS,5I4//)
      END                                                                 DOT70280
C
C
      SUBROUTINE DOT6
      DIMENSION II(8),KDUMMY(2)                                           DOT40010
      DIMENSION LDUMMY(407),X(193)                                        DOT40020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5         DOT50010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7             DOT50020
```

```
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN          DOT50030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5           DOT50040
      COMMON L6,L7,L8,KCUNT6,NRECRD,KLONG,X
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(  DOT50060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                             DOT50070
      DEN=J1*J2*J3*J4*J5*J6                                            DOT70030
      WRITE (3,1600)K6,K5,K4,K3,K2,K1                                  DOT70040
      DO 1602 L8=1,J8                                                  DOT70050
      II(K8)=L8                                                        DOT70060
      DO 1602 L7=1,J7                                                  DOT70070
      II(K7)=L7                                                        DOT70080
      DO 1601 L6=1,J6                                                  DOT70090
      II(K6)=L6                                                        DOT70100
      DO 1601 L5=1,J5                                                  DOT70110
      II(K5)=L5                                                        DOT70120
      DO 1601 L4=1,J4                                                  DOT70130
      II(K4)=L4                                                        DOT70140
      DO 1601 L3=1,J3                                                  DOT70150
      II(K3)=L3                                                        DOT70160
      DO 1601 L2=1,J2                                                  DOT70170
      II(K2)=L2                                                        DOT70180
      DO 1601 L1=1,J1                                                  DOT70190
      II(K1)=L1                                                        DOT70200
      J=INDEX(I1)                                                      DOT70210
 1601 SUM=SUM+X(J)                                                     DOT70220
      SUM2=SUM2+SUM*SUM                                                DOT70230
      VALUE=SUM/DEN                                                    DOT70240
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                     DOT70250
 1602 SUM=0.0                                                          DOT70260
      RETURN                                                           DOT70270
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                   DOT70010
 1600 FORMAT (/23H SUMMATION OVER FACTORS,6I4//)
      END                                                              DOT70280
C
C
      SUBROUTINE DOT7
```

```
      DIMENSION II(8),KDUMMY(2)                                         DOT40010
      DIMENSION LDUMMY(407),X(193)                                      DOT40020
      COMMON IRECRD,ISECTR,I,J,K,NFCTRS,KOUNT1,N,KOUNT4,II,KOUNT5       DOT50010
      COMMON KONST1,KONST2,KONST3,KONST4,KONST5,KONST6,KONST7           DOT50020
      COMMON J2,K2,J3,K3,KDUMMY,L2,L1,L3,L4,LDUMMY,ADUMMY,DEN           DOT50030
      COMMON SUM,SUM2,J1,J4,J5,J6,J7,J8,K1,K4,K5,K6,K7,K8,L5            DOT50040
      COMMON L6,L7,L8,KOUNT6,NRECRD,KLONG,X
      EQUIVALENCE (II(1),I1),(II(2),I2),(II(3),I3),(I4,II(4)),(I5,II(   DOT50060
     15)),(II(6),I6),(II(7),I7),(II(8),I8)                              DOT50070
      DEN=J1*J2*J3*J4*J5*J6*J7                                          DOT70030
      WRITE (3,1700)K7,K6,K5,K4,K3,K2,K1                                DOT70040
      DO 1702 L8=1,J8                                                   DOT70050
      II(K8)=L8                                                         DOT70060
      DO 1701 L7=1,J7                                                   DOT70070
      II(K7)=L7                                                         DOT70080
      DO 1701 L6=1,J6                                                   DOT70090
      II(K6)=L6                                                         DOT70100
      DO 1701 L5=1,J5                                                   DOT70110
      II(K5)=L5                                                         DOT70120
      DO 1701 L4=1,J4                                                   DOT70130
      II(K4)=L4                                                         DOT70140
      DO 1701 L3=1,J3                                                   DOT70150
      II(K3)=L3                                                         DOT70160
      DO 1701 L2=1,J2                                                   DOT70170
      II(K2)=L2                                                         DOT70180
      DO 1701 L1=1,J1                                                   DOT70190
      II(K1)=L1                                                         DOT70200
      J=INDEX(I1)                                                       DOT70210
 1701 SUM=SUM+X(J)                                                      DOT70220
      SUM2=SUM2+SUM*SUM                                                 DOT70230
      VALUE=SUM/DEN                                                     DOT70240
      WRITE (3,13)SUM,DEN,VALUE,(II(J),J=1,NFCTRS)                      DOT70250
 1702 SUM=0.0                                                           DOT70260
      RETURN                                                            DOT70270
   13 FORMAT (F18.8,F18.8,F18.8,8I3)                                    DOT70010
 1700 FORMAT (/23H SUMMATION OVER FACTORS,7I4//)
      END
```

APPENDIX C

APPENIX C

```
C     INPUT DATA
C
C
C
C     EXPERIMENT I DATA
C     ERROR SCORES
C     EACH ROW REPRESENTS THE SCORES IN ONE CELL
C     THE ORDER IS X-SUB-NISAR
C     WHERE THE EXTREME RIGHT HAND SUBSCRIPT INCREASES FIRST
  2.70  2.90  2.60  3.60  3.00  2.40  2.80  3.50  2.70  2.90
  2.80  3.50  2.30  2.90  2.60  3.20  3.90  3.70  2.60  2.20
  1.90  2.50  1.70  3.00  2.20  2.70  2.50  2.80  3.20  2.50
  3.60  3.40  3.70  3.50  3.30  2.30  2.90  2.90  1.60  3.50
  3.00  3.40  3.70  3.00  3.30  3.50  2.40  3.50  3.40  3.30
  2.90  3.30  2.20  2.70  3.20  1.60  3.40  1.60  3.40  3.20
  2.00  2.10  1.70  2.70  2.60  3.00  2.50  2.20  2.80  2.80
  2.90  3.20  3.20  3.20  3.40  3.50  3.20  3.60  3.00  3.10
  3.40  3.30  3.00  3.80  3.80  3.40  2.90  2.70  3.50  3.30
  3.60  3.50  3.40  3.30  3.40  3.40  3.40  3.30  3.00  3.40
  2.90  3.30  3.40  3.10  3.50  3.40  3.20  2.50  2.70  2.30
  3.30  2.10  3.40  3.50  3.70  3.10  3.60  3.40  2.20  2.60
  2.60  3.40  2.80  3.10  3.40  2.30  2.80  2.10  3.40  2.60
  2.50  3.20  2.50  1.80  3.30  3.70  3.00  3.70  3.10  2.50
  2.60  3.20  1.60  2.90  2.80  1.90  2.60  2.30  3.00  3.60
  2.20  2.00  1.80  3.10  1.90  3.10  3.50  3.10  2.70  2.80
  3.00  3.20  3.20  3.50  3.20  3.30  2.00  2.70  3.00  2.90
  2.10  3.50  3.40  2.80  3.40  3.50  3.30  2.90  2.70  3.60
  2.40  2.80  3.10  3.10  3.50  3.10  2.60  2.10  2.90  3.50
  3.00  3.10  3.60  3.20  3.20  2.90  2.90  3.70  3.20  2.80
  3.00  2.20  2.60  3.60  3.20  3.30  3.10  3.10  3.20  2.20
  3.40  3.20  3.30  3.40  3.30  3.30  3.50  3.40  3.40  3.20
  1.50  2.70  2.90  2.80  2.40  3.40  1.90  2.80  3.00  2.40
  3.60  3.70  3.50  3.20  2.30  3.10  2.50  2.10  3.00  2.90
```

```
C
C
C
C
C
C
C      EXPERIMENT I DATA
C      TIME SCORES
C      EACH ROW REPRESENTS THE SCORES IN ONE CELL
C      THE ORDER IS X-SUB-NISAR
C      WHERE THE EXTREME RIGHT HAND SUBSCRIPT INCREASES FIRST
  64.42 53.72 41.75 27.89 26.09 77.91 44.21 35.88 45.17 46.33
  65.17 38.17 50.89 71.04134.06 94.66 36.75 34.29 67.08 91.33
  72.12 83.53 86.79 35.09 45.08 50.78 36.83 42.33 46.68 55.47
  59.50 51.50 51.05 43.50 57.78 96.50 55.49 79.22111.58 48.35
  49.54 23.93 25.19 38.22 37.40 38.31 49.25 35.65 57.04 39.39
  55.42 44.48 97.33 56.57 45.05 56.36 50.60 71.88 67.23 54.64
  35.92 37.95 63.26 41.51 46.89 41.44 34.85 62.86 43.91 35.40
  62.63 74.49 76.52 65.30 54.26 81.20 52.22 73.41 65.15 47.81
  62.55 90.23146.20 43.32 65.05 48.19 71.58 41.30 33.14103.30
  29.44 45.98 71.62106.50 35.30 70.29 41.33 51.00 54.47 39.16
  58.28 55.80 34.50 38.79 46.00105.50 64.81 53.06112.90 60.69
  42.69 49.06 23.65 33.16 26.80 28.37 39.06 51.05 67.34 36.00
  53.00 51.53 45.50 59.75 36.37 55.31 50.43105.10 27.35 45.73
  41.31 41.54 69.71108.21 50.24 42.82 33.43 24.54 27.22 47.86
  54.45 83.77 61.30 69.59 87.00181.79 75.50 87.66 67.55 69.12
 134.25 70.91 95.80 75.11121.98 43.90 42.11 61.86 46.25 40.60
  51.04 35.75 47.59 40.90 38.13 27.47 48.13 80.40 31.60 21.06
  59.95 41.92 46.76 56.23 53.92 47.67 87.62 65.35 70.64 20.46
  53.25 51.12 69.51 36.92 44.63 33.17 64.08 89.22103.82 46.93
  62.82 30.80 53.48 49.54 61.18 65.83 66.08 47.32 49.02 69.97
 103.61 67.88 55.26 43.87 65.54 53.88 52.61 85.18 52.34107.08
  36.09 41.51 40.66 38.63 57.96 43.24 33.54 55.79 28.74 41.80
  74.19 49.45 55.60 26.19 24.84 31.84 58.42 61.04 50.43 48.00
  46.86 29.54 62.98 37.50 74.06 28.51 45.81 86.13 39.50 61.68
```

```
C
C
C
C
C
C
C     EXPERIMENT II DATA
C     ERROR SCORES
C     EACH ROW REPRESENTS THE SCORES IN ONE CELL
C     THE ORDER IS X-SUB-NISAR
C     WHERE THE EXTREME RIGHT HAND SUBSCRIPT INCREASES FIRST
  2.70  2.90  2.60  3.60  3.00  2.40  2.80  3.50  2.70  2.90
  2.80  3.50  2.30  2.90  2.60  3.20  3.90  3.70  2.60  2.20
  1.90  2.50  1.70  3.00  2.20  2.70  2.50  2.80  3.20  2.50
  3.60  3.40  3.70  3.50  3.30  2.30  2.90  2.90  1.60  3.50
  3.20  3.20  3.00  3.10  3.40  3.30  3.00  2.70  3.30  2.20
  3.40  3.50  2.60  2.70  3.00  3.20  3.30  3.10  3.60  3.10
  3.80  3.50  2.80  1.60  3.10  3.20  3.20  2.90  3.30  3.00
  2.40  3.30  2.90  3.30  2.40  3.70  2.30  3.80  3.20  3.90
  2.70  3.00  3.40  3.20  2.30  2.00  2.90  2.40  3.70  2.80
  2.70  3.10  3.10  2.90  3.70  3.20  3.20  3.60  3.30  3.10
  2.70  3.40  2.00  1.90  3.30  2.70  2.80  3.40  3.60  3.80
  3.30  1.90  3.70  3.20  3.70  3.20  3.20  2.80  3.70  3.60
  2.60  3.40  2.80  3.10  3.40  2.30  2.80  2.10  3.40  2.60
  2.50  3.20  2.50  1.80  3.30  3.70  3.00  3.70  3.10  2.50
  2.60  3.20  1.60  2.90  2.80  1.90  2.60  2.30  3.00  3.60
  2.20  2.00  1.80  3.10  1.90  3.10  3.50  3.10  2.70  2.80
  2.80  3.00  3.10  3.20  2.70  2.80  2.70  3.00  3.00  3.60
  3.50  2.90  3.10  2.60  3.00  3.40  2.50  3.50  3.50  3.40
  3.60  3.30  3.30  3.30  3.00  3.00  3.00  2.40  3.00  3.10
  2.20  3.10  3.20  3.00  3.50  3.80  2.70  3.20  3.60  3.30
  3.10  2.40  3.20  3.40  3.00  2.10  2.90  3.20  1.90  2.80
  3.00  2.90  3.60  3.50  3.80  3.40  3.30  3.20  3.50  3.50
  3.10  3.10  2.90  3.50  3.40  3.20  3.10  3.00  2.80  3.10
  3.50  2.80  3.50  3.30  2.50  3.40  3.50  3.20  3.60  2.90
```

```
C
C
C
C
C
C
C      EXPERIMENT II DATA
C      TIME SCORES
C      EACH ROW REPRESENTS THE SCORES IN ONE CELL
C      THE ORDER IS X-SUB-NISAR
C      WHERE THE EXTREME RIGHT HAND SUBSCRIPT INCREASES FIRST
 64.42 53.72 41.75 27.89 26.09 77.91 44.21 35.88 45.17 46.33
 65.17 38.17 50.89 71.04 92.00 94.66 36.75 34.29 67.08 91.33
 72.12 83.53 86.79 35.09 45.08 50.78 36.83 42.33 46.68 55.47
 59.50 51.50 51.05 43.50 57.78 96.50 55.49 79.22 59.00 48.35
 34.71 33.20 37.21 30.11 33.20 33.18 56.83 60.12 32.73 46.89
 35.72 47.23 64.54 47.66 46.35 49.96 26.34 78.65 34.67 47.93
 47.97 59.23 74.01138.47 68.46 46.93 55.54 58.70 70.97 80.56
 59.48 40.07 44.05 67.75 65.52 39.33 50.08 44.73 70.72 28.20
 42.47 39.15 51.09 57.85 73.05 58.45 75.66 34.65 41.55 52.65
 49.52 80.07 47.35 49.82 57.87 39.31 75.87 48.22 49.97 50.93
 69.58 51.53 43.30 60.68 73.21 71.86 55.46 41.26 35.49 54.51
 32.38106.58 35.91 44.40 34.76 26.81 45.20 49.98 37.94 30.07
 53.00 51.53 45.50 59.75 36.37 55.31 50.43 55.00 27.35 45.73
 41.31 41.54 69.71 50.00 50.24 42.82 33.43 24.54 27.22 47.86
 54.45 83.77 61.30 69.59 87.00 86.00 75.50 87.66 67.55 69.12
 72.00 70.91 95.80 75.11 60.20 43.90 42.11 61.86 46.25 40.60
 87.70 72.61 78.71 41.24 61.61 63.95 54.64 50.00 55.12 68.32
 72.36 62.71 80.52 65.91 43.10 50.86 58.50 71.62 34.02 49.59
 60.95 34.75 42.55 56.61 37.20 57.56 49.43 55.74 50.35 56.05
 68.17 95.42 60.78 65.70 55.87 46.30 36.45 50.04 62.36 68.47
 20.87 38.54 47.91 34.90 27.72 65.87 51.98 22.75 42.21 54.18
 63.21 71.97 45.74 43.34 40.38 39.51 40.66 55.77 42.34 39.34
 73.53 42.01 74.99 63.93 36.43 49.90 32.71 65.22102.78 60.16
 59.97 64.84 28.23 91.03 93.22 45.38 79.00 30.28 58.68 78.47
```

APPENDIX D

APPENDIX D

INFORMATION* AS A MEASURE OF LEARNING

One of the major problems in investigating learning behavior is that of finding an appropriate measure of learning. The normal practice is for an experimenter to observe behavior from which he infers learning which he scales in some manner. A simple scale would consist in the assignment of behavior to perhaps each of two categories depending on the inference of learning or no learning, and recording a "yes" or a "no". This implies that each time the subject faces a choice decision that there must be a "right choice" and a "wrong choice". These choices are classified as right or wrong by the experimenter.

The latter method has the disadvantage of introducing experimenter bias to a great degree. Instead of just recording behavior he is also imposing on the behavior a logical structure which may be artificial. Error scores, for example, do not necessarily show wrong learning or no learning. If a child, for example, answers the question: "How much is 7 + 12?" as 20 _everytime_, the child has obviously _learned_ the wrong answer, and a simple error score would not reveal this as learning.

The basic test supporting an inference of learning is repeated behavior. For subjects that cannot verbalize, it is the only indication. The basic measure of learning then should be based on records of behavior.

---

* Information, as used here, is an identical term for negentropy (Brillouin, 1962).

This measure should also allow comparisons of learning among a set of organisms.

The problem may be stated as follows: let the subject be faced with a sequence (or set) of choices C_i, i = 1, 2, ..., n. Let there be m_i possible responses at each choice point. Find an appropriate measure to determine if a certain pattern of responses has been learned.

A large body of literature has been developed utilizing the notion of response probability (Atkinson, Bower, and Grothers, 1965). It is this idea that we want to incorporate into a measure of learning using the tools of information theory.

The amount of information H obtained from an event, such as a run through a maze, which has n possible outcomes each with response probability P_j, j = 1, 2, ..., n is defined to be

$$H = -\sum P_j \log_2 P_j \tag{9}$$

$$\text{where } \sum P_j = 1.0 \quad \text{and}$$
$$0 \le P_j \le 1.0 \quad \text{for all } j .$$

It could be verified that H is maximum when $P_j = P$ for all j, i.e. all outcomes are equally likely, and that H = 0 when one outcome is certain (Goldman, 1953; Brillouin, 1962; Raisbeck, 1964).

As P_j approaches 1.0, hence $\log_2 P_j$ approaches zero, P_ℓ approaches zero $\ell \neq j$ for some trial (k) and H approaches zero. i.e. the smaller the initial uncertainty about the outcomes, the smaller the amount of information gained from a run. When one outcome becomes certain no information is gained by the occurence of the event, and it may be said that the animal (subject) has learned. Another way of viewing the latter statement is that if an outcome is certain, this will be demonstrated by the identical repetition of behavior. This is a demonstration of learning. If one has not learned, i.e., the response is uncertain, then information is gained from the trial which will affect the succeeding outcomes.

There is ample literature (Tolman, 1939; Estes, 1960; Audley, 1960; Spence, 1960; Atkinson, 1960; La Berge, 1962) demonstrating that choices (choice behavior) at a decision point in lower animals are random. As the event (trial) is repeated, the probabilities are modified until P_j approaches 1.0 for some k. The question arises then, is this modification a cognitive process or is it the result of chemical and mechanical processes stimulated by the trial behavior.

Since a living organism can be considered an energy-system (Duffy, 1962), it is suggested here that the criterion for modification of choice behavior is the minimization of energy. The organism will discover that repetitive pattern which in a given situation will minimize energy. This concept of minimum energy has been touched upon by some investigators (Washburn, 1926; Milsum, 1966) but has never been used to advantage in learning theory.

The trial and error behavior exhibited by self-organizing and adaptive systems (living organisms) permits the system to search for a stable equilibrium state which will enhance its probability of survival. In attaining this equilibrium state, the behavior of the organism suggests that it may be using some principle of economy of energy consistent with its survival. (In the maze problem, for example, the rat always chose the shortest path, RRRR, to the goal - i.e. the minimum energy path - when learning was achieved.)

The maze in our experiment consists of four actual choice points and four pseudo-choice points (Chapter II). At each actual choice point the rat was faced with making a decision for which it was scored with an R or W. The sequence of combinations of R, W or both consisting of four elements, defined the path the rat chose. Retrace of a path or part of a path was not considered due to the lack of foresight on our part to record these events during the experiment. At each actual choice point, therefore, there are two possible outcomes, each of which can be initially assumed to be equally likely. The maximum information in a maze run is therefore:

$$-\sum_{i=1}^{4} P_i \log_2 P_i = -\sum_{i=1}^{4} \frac{1}{2} \log_2 \frac{1}{2} = 4 \text{ bits} \tag{10}$$

at the start of the experiment for each animal. As the experiment progressed, the response probabilities were computed by

$$P_j^* = \frac{\text{number of times choice j is made}}{\text{total number of choices}} \tag{11}$$

for each choice point. The probability of correct response at each choice point is plotted vs. trial number as shown in Figures D-1 through D-4. A composite plot for all four choice points is shown in Figure D-5. The total information gained on any trial is then computed as

$$H = -\sum_{j=1}^{4} P_j^* \log_2 P_j^* \tag{12}$$

Figures D-6 and D-7 illustrate some of our experimental results. In Figure D-6, as the trial number increases, the behavior is less random, the information gained (H or negentropy) from the trial approaches zero, and the amount learned has evidently increased. In Figure D-7, it can be seen that as the trial number increases, the information gained (H) does not show a decreasing trend. This indicates that there is still a considerable amount of random behavior and consequently the trials have resulted in very little learning. (As shown by the graph legend, this was due mainly to the effects of noise.)

It should be noted that if a rat were to make consistently wrong choices the measure index (H or negentropy) would still show learning. However, this did not occur (as demonstrated by our experiment) because it violates the concept of minimum energy expenditure. In other words, the following two conditions must be simultaneously satisfied.

1. H must approach zero (necessary condition).
2. The path chosen must be the minimum energy path (sufficient condition).

It should be further noted that this measure (H) allows learning comparisons just as error or time scores do. What makes this measure (H) unique, however, is that it points out consistency in behavior.

A possibly useful model for simulating the probabilistic learning system could be constructed as a special kind of Markov chains, called "random walks with an absorbing barrier." The assumptions underlying the construction of such models have been well explained by La Berge (1962), Atkinson (1960) and Atkinson, Bower and Crothers (1965). The random walk model is best explained in a diagrammatic form (Figure D-8).

There are nine different positions or "states": the states S_i, $i = 0, 1, 2 \ldots, 9$. The arrows between any two states represent possible transitions. Beside each arrow is written the probability that the transition occurs next when the subject is in the state at the origin of the arrow. The state S_9 has an arrow only back to itself, with associated

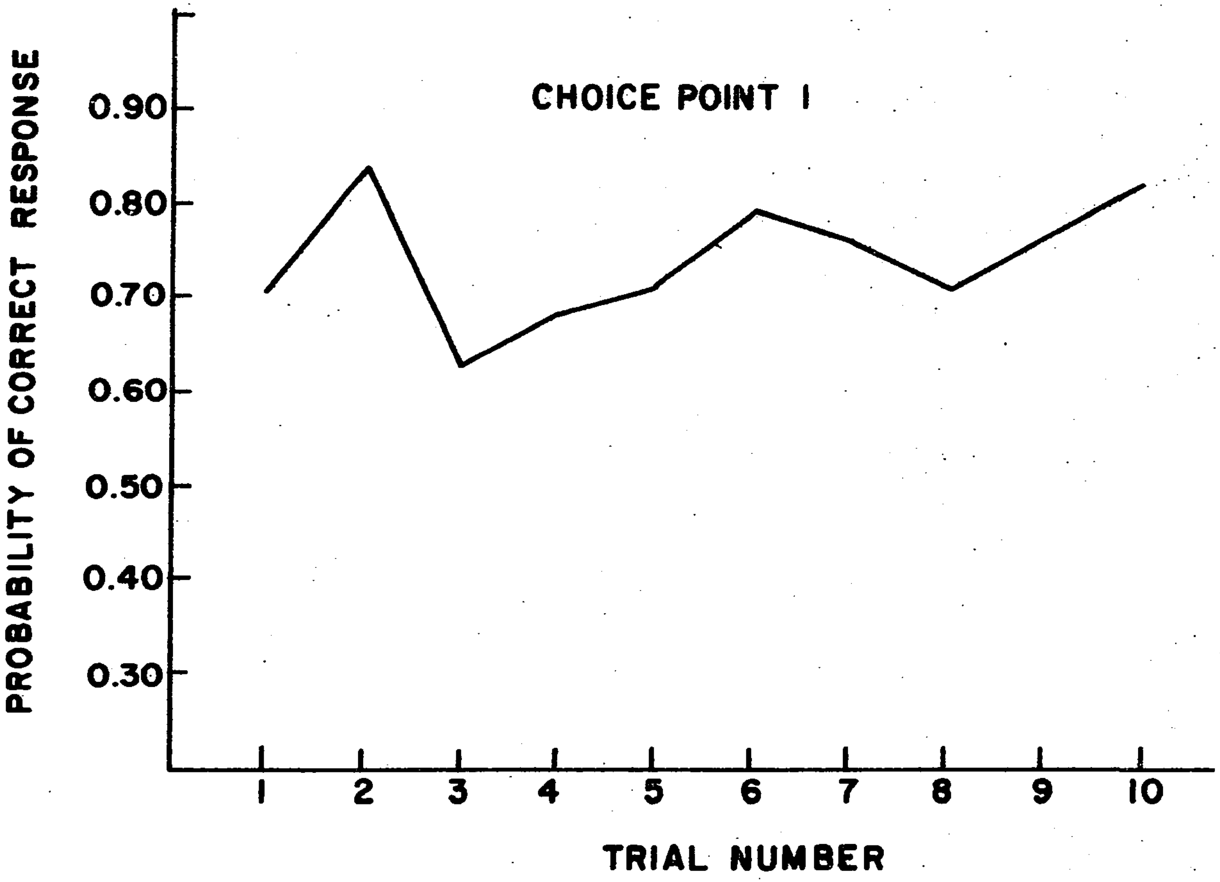


FIGURE D-1. PROBABILITY OF CORRECT RESPONSE AT CHOICE POINT 1 (S_1)

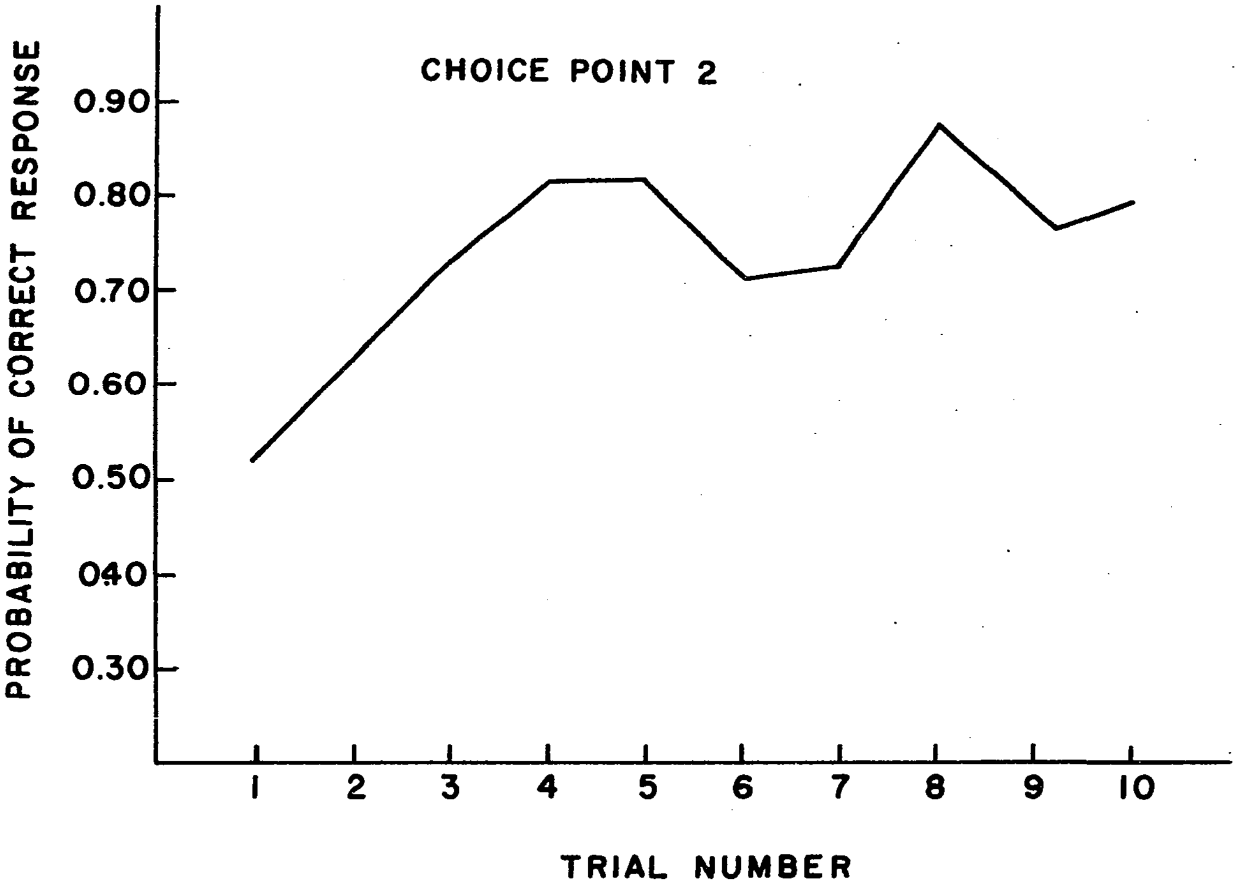


FIGURE D-2. PROBABILITY OF CORRECT RESPONSE AT CHOICE POINT 2 (S_3)

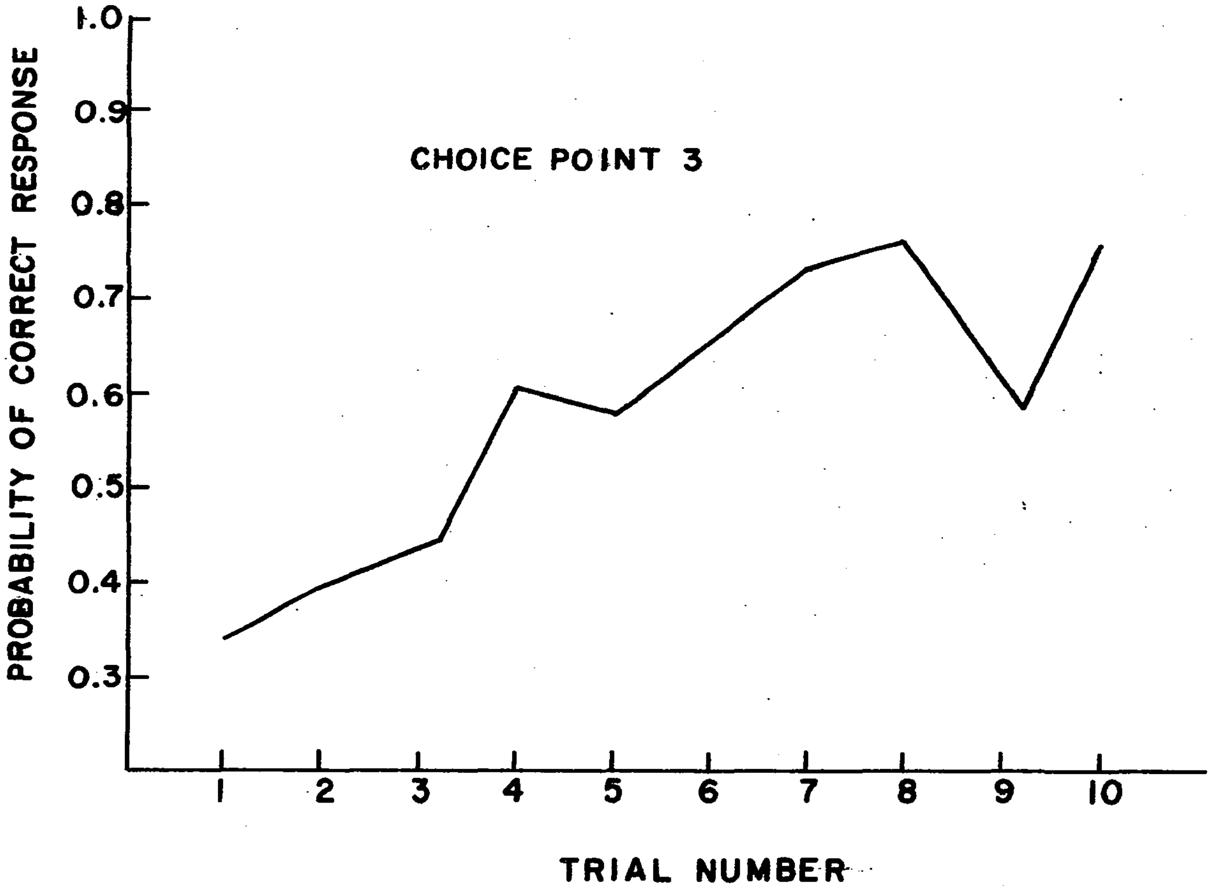


FIGURE D-3. PROBABILITY OF CORRECT RESPONSE AT CHOICE POINT 3 (S_5)

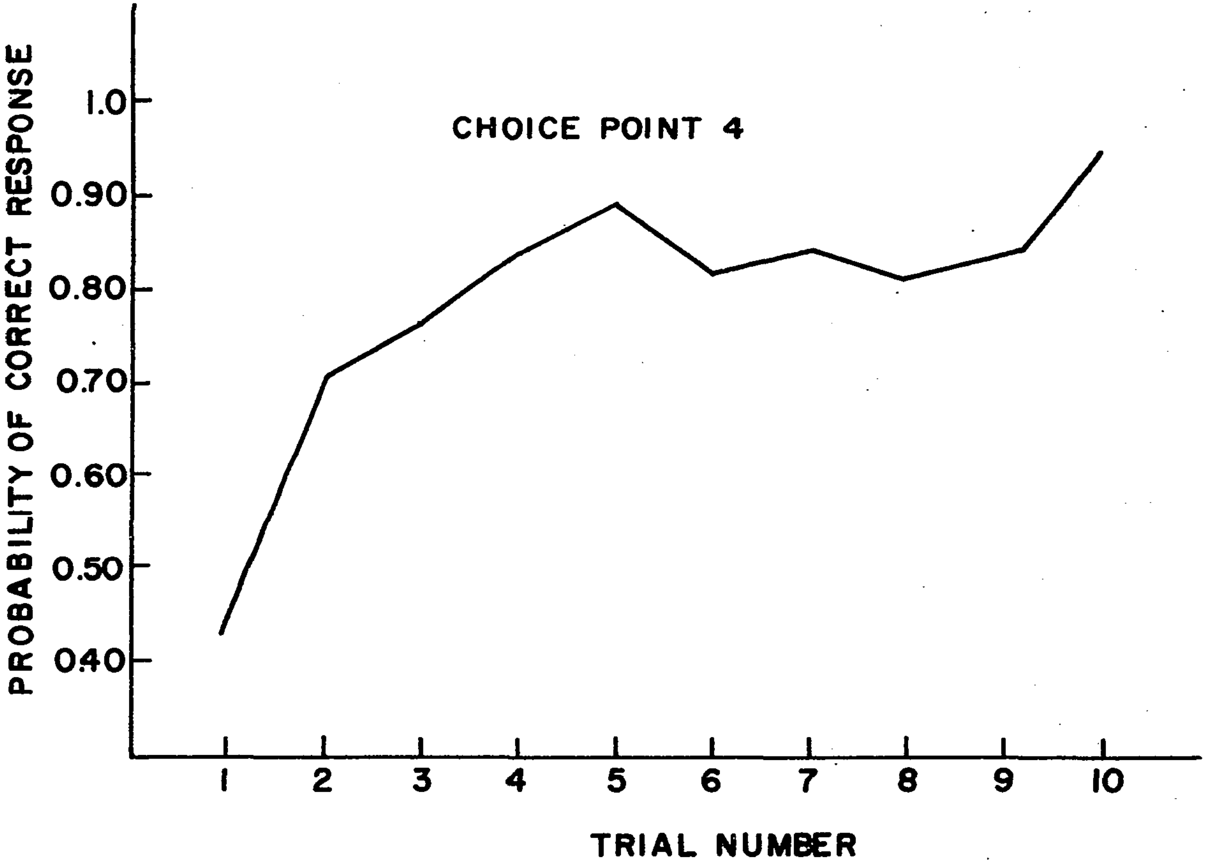


FIGURE D-4. PROBABILITY OF CORRECT RESPONSE AT CHOICE POINT 4(S_7)

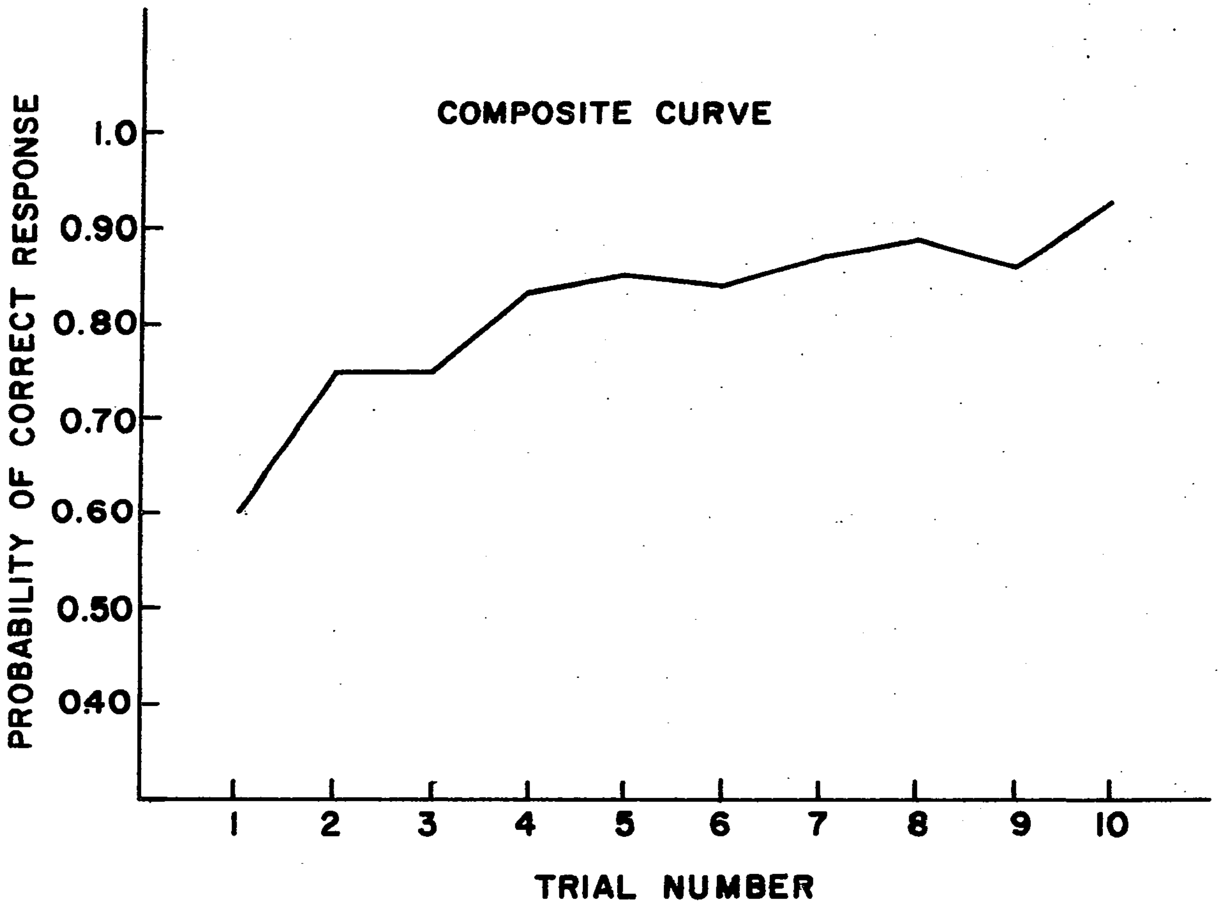


FIGURE D-5. PROBABILITY OF CORRECT RESPONSE AT ALL FOUR CHOICE POINTS

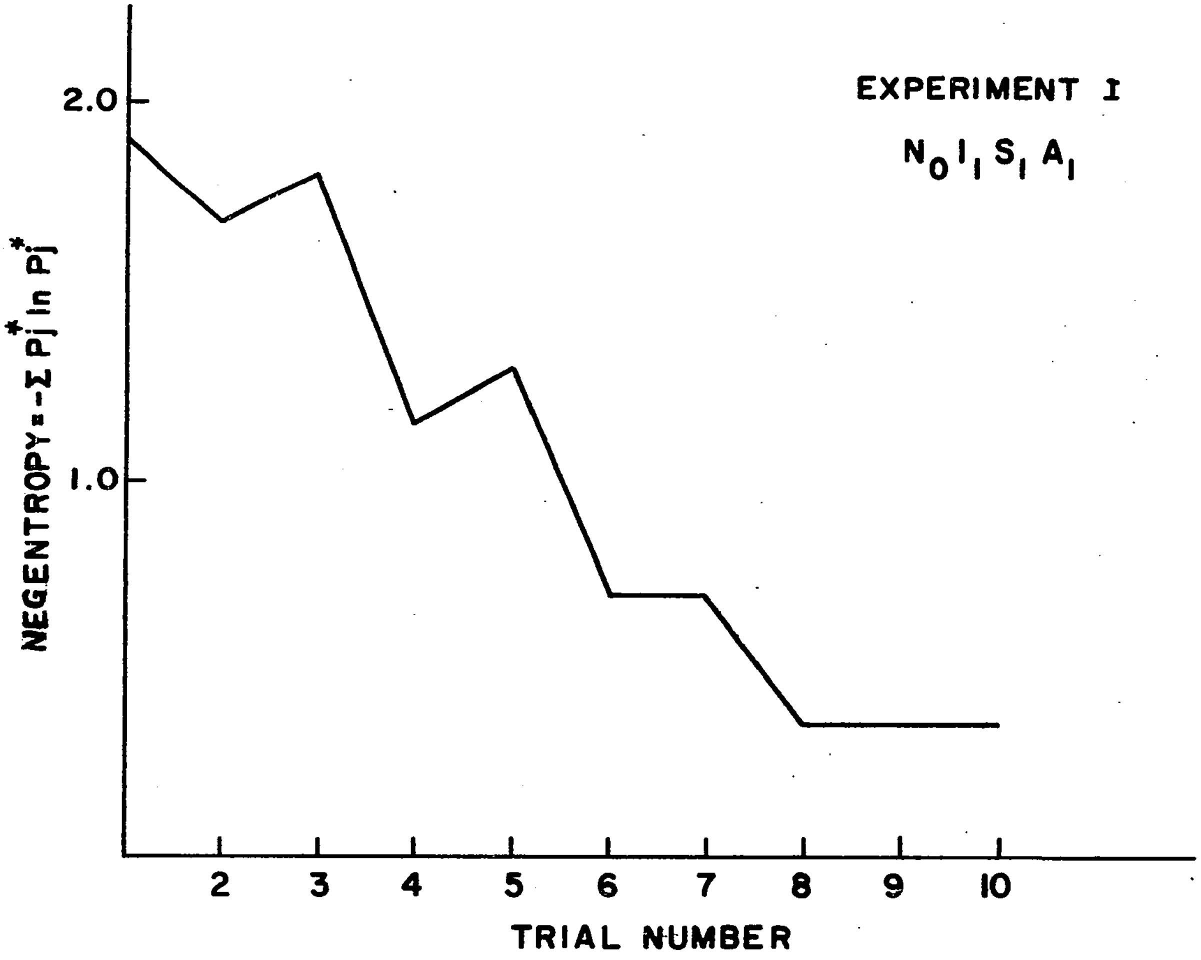


FIGURE D-6. NEGENTROPY OF THE RAT-MAZE SYSTEM
This curve is based on the response probabilities at the four actual choice points.

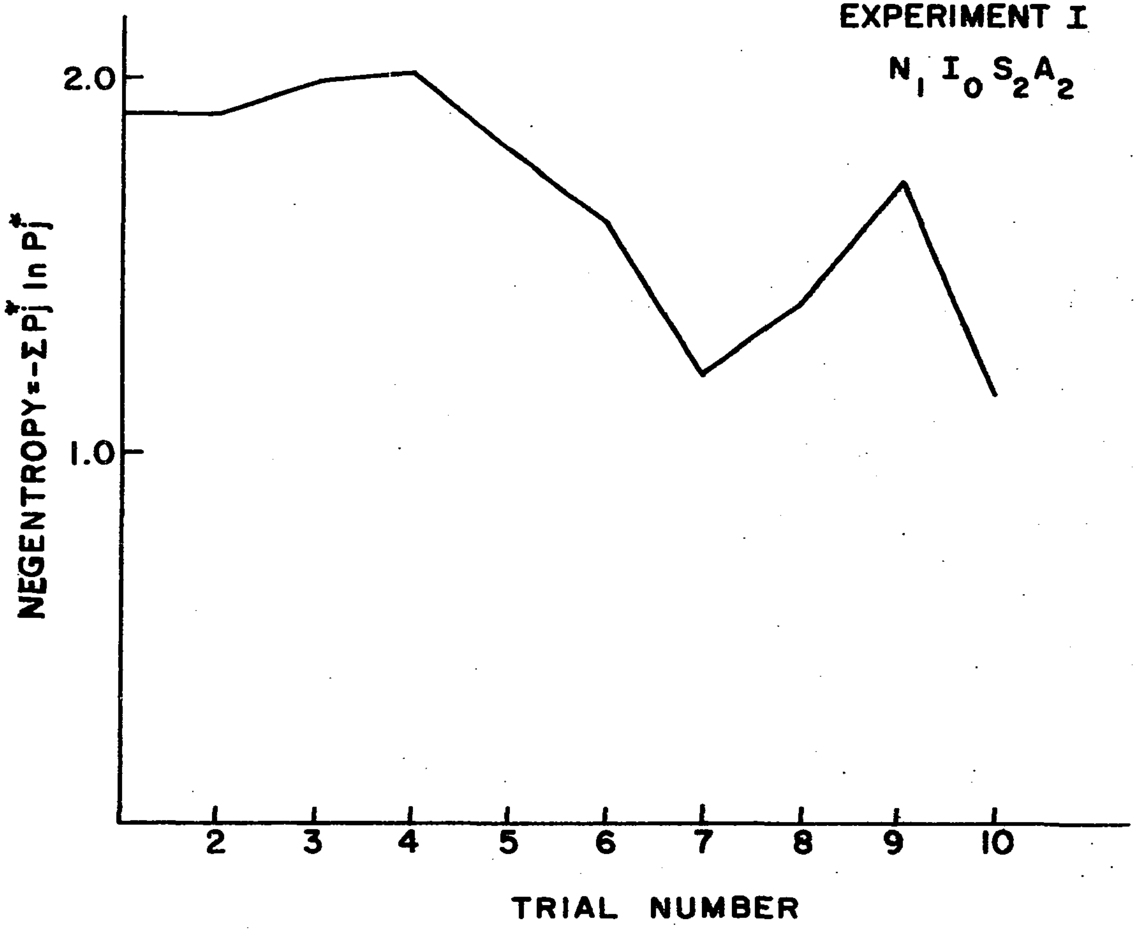


FIGURE D-7. NEGENTROPY OF THE RAT-MAZE SYSTEM
This curve is based on the response probabilities at the actual choice points.

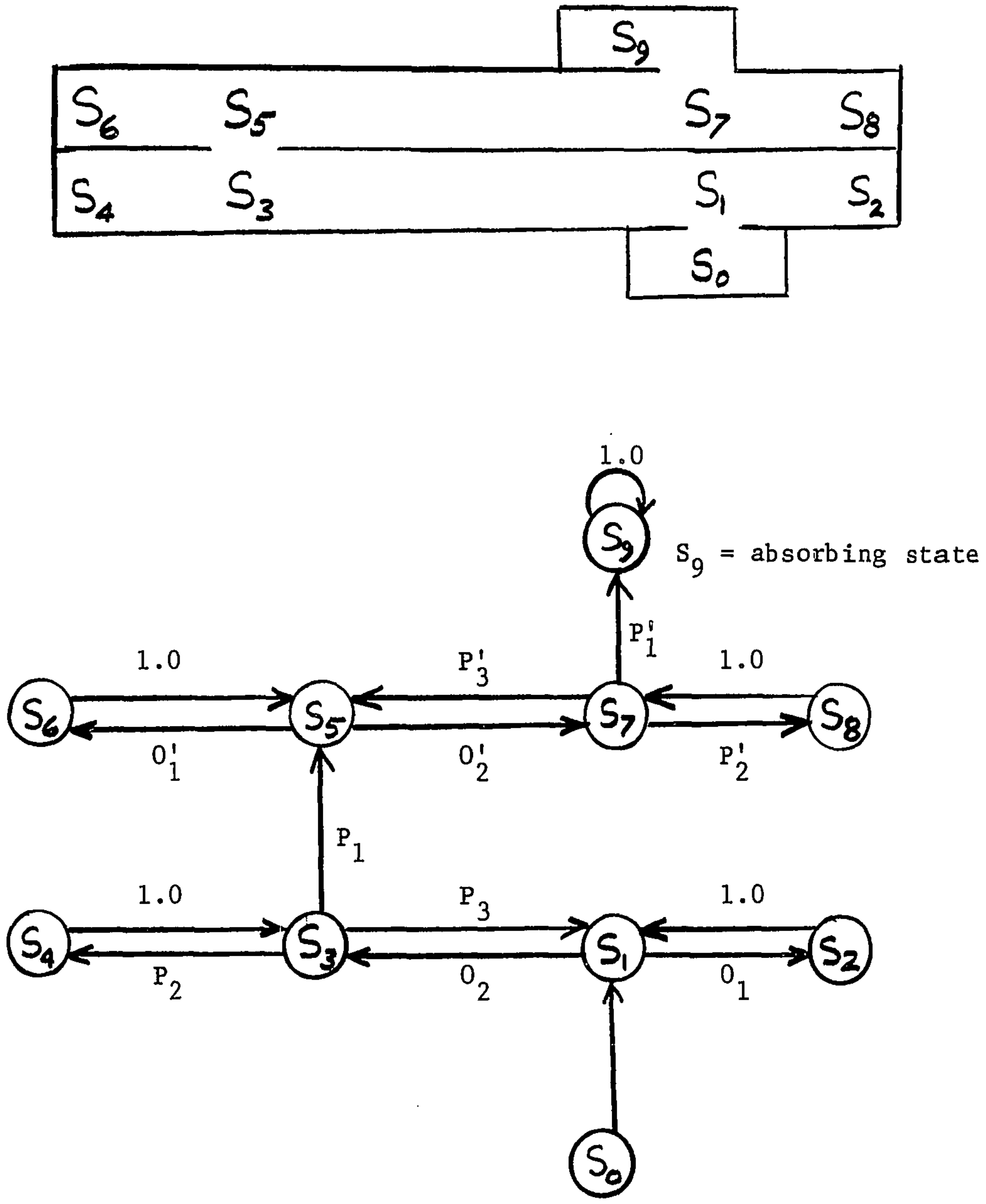


FIGURE D-8. STATE TRANSITION DIAGRAM OF A RANDOM WALK MODEL FOR CHOICE BEHAVIOR transition probability of unity. This identifies S_9 as an "absorbing state" in the sense that once the subject enters this state the opportunity for any further state transitions is terminated, and that the experimental trial (trial begins by introducing the subject at S_o) is ended.

It is obvious that in order to give a complete mathematical analysis, which would permit simulation the probabilities associated with retracing are required. The constraint equations

$$O_1 + O_2 = 1.0$$

$$P_1 + P_2 + P_3 = 1.0$$

$$O_1' + O_2' = 1.0$$

and $$P_1' + P_2' + P_3' = 1.0$$

can then be used to predict the most probable path the rat would choose at any trial. However, as mentioned earlier these retrace probabilities were not recorded during the course of this study and therefore a proper simulation would not be of any practical value at this time. It is recommended that in future work the path of the subject be recorded including retrace, for this would then furnish the required information to enable the experimenter to write the proper mathematical relations describing the system.