A LABORATORY INTRODUCTION TO PSYCHOLOGY

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PREFACE

Psychology is a science, and one of the main scientific methods it employs is laboratory experimentation. The purpose of this manual and of the introductory laboratory course is to acquaint the student with the concepts and methods of laboratory science as they apply to psychology.

It is assumed that the laboratory course will follow or accompany a comprehensive course in introductory psychology which emphasizes scientific topics. We do not burden our text with an extensive review of relevant facts nor thoroughly acquaint the student with the general topic. We have related our experiments to journal articles and to sections of several popular textbooks[1] so that students and instructors will have ready access to introductory material.

This manual contains many new experiments. Fine old standards often are replaced by new experiments because of evolution in inquiry. In recent years, psychologists have been able to ask clearer questions and answer them more definitely than was possible twenty or thirty years ago. Sometimes this has required the introduction of complicated apparatus or elaborate analysis; but sometimes it has been possible, by gaining certain theoretical insights, to simplify methods while increasing stability. It is not so much equipment and methodology that lead to good science, as it is the posing of the proper question.

In a laboratory manual one can hardly discuss every facet of psychology; it is really not necessary to be that comprehensive. Students will spend at least a week, perhaps several weeks, on a single, narrow topic; thus, in one semester, many different topics cannot be covered. This manual is limited to standard topics of experimental psychology, but includes some experiments that are relatively new. We include only those which can be performed with simple apparatus that is available in most teaching laboratories.[2] Many of the experiments require nothing more than this manual and enough students to provide reasonable samples of behavior. The experiments we have chosen often do not have obvious solutions, and thus are not mere exercises.

We have grouped the topics discussed in three main categories: Animal Behavior, Sensory Processes, and Human Behavior. Within each of these sections, the experiments are somewhat connected in shorter series. The Animal Behavior studies include one series consisting of conditioning, extinction, discrimination, and secondary reinforcement, and a second series on schedules of reinforcement and motivation.

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[1]See Table 1 at the end of the Preface, and references at the end of each exercise.

[2]See Table 2 at the end of the Preface.

The experiments on Sensory Processes include some threshold measurements, and also a series of studies on perceived magnitude, adaptation level, and illusions. The experiments on Human Behavior include a series on learning and transfer, on short-term memory, and on two-person interactions.

We use series of experiments, rather than the usual collection of "one-shot" experiments, because our experience indicates that students in introductory laboratory courses do not really begin to understand an experiment until it has been completed. We find that a student who may be confused and inept in the first experiment of a series is often relatively confident and interested if given a second or third study to do so long as the studies are sufficiently similar to permit the usage of the same procedures and basic ideas. As a result the student does more and better work, and frequently has data good enough to justify the writing of a careful and serious report.

Finally, in our selection, we have attempted to find experiments that do not depend on subtle instructions or social atmospheres, and that do not depend at all on misdirecting the subject. When students are both experimenters and subjects, as is usual in laboratory courses, only details of procedure can be hidden but the aim of the experiment and the general implications of behaviors cannot.

The experiments expose students to a variety of problems. The Animal Behavior experiments involve many complications in procedure, but use fairly simple analyses. The methods of analysis become more complex, and some of the interpretations more difficult, in the experiments on Sensory Processes. In those on Human Behavior, the structure of the behavior is relatively complicated, and students usually find that the explanations offered and the interpretation of the findings present interesting problems.

The nineteen experiments which comprise this manual probably could not be finished by a class taking the usual laboratory course. The Animal Behavior experiments are particularly time-consuming, and may be delayed if certain rats are, for a while, uncooperative. Thus, as with most laboratory manuals, this one is designed to give the individual instructor and class a wide choice. We do recommend that the instructor try to use at least one or two of our experimental series, to see how they work for him, rather than just performing the first experiment of each group.

The manual is supplemented by three main appendixes: one on the analysis of data, one on the use of random number tables for experimental design, and one on the preparation of experimental reports. These three topics are needed in all of the experiments and cannot be covered in any one experiment. These appendixes probably should be studied early in the course, but can be used for reference. There is a fourth appendix which lists instructions for Experiment 19.

This manual is a revision of the one which has been in use for the past several years in the Psychology Department of Indiana University and its extension centers. We are indebted to the contributors to the previous edition, particularly James Dinsmoor, Donald Lauer, and Lloyd Peterson, and to the many others who made helpful suggestions, criticisms, and contributions of material.

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TABLE 1

SUGGESTED READINGS AND REFERENCE MATERIALS FOR STUDENTS[a]

Experiment No. and Topic	A[b]	B	C	D	E
1. Acquisition, extinction, spontaneous recovery	–	423–100	–	73–92	188–221
2. Discrimination	–	–	582–613	97–98	–
3. Secondary reinforcement	P–60 P–377	–	679–683	–	–
4. Schedules of reinforcement	–	–	–	93–96	206–212
5. Partial reinforcement effect in extinction	P–215	–	563–565	–	–
6. Motivation	–	–	657–678	203–230	233–263
7. Difference threshold	–	458	192–233	271–279	97
8. Physical magnitude	P–336 P–569	–	234–266	279–280	–
9. Adaptation level	–	–	363–365	–	–
10. Relative size illusion	P–157	–	–	–	163–169
11. Visual acuity	–	–	382–387	304–307 280–288	99–114
12. Transfer of training	–	–	733–767	115–158	300–321
13. Short-term memory	–	–	–	–	–
14. Short-term memory	–	499	–	–	–
15. Short-term memory	–	419	–	115–158	328–344
16. Serial Position	–	482	–	–	–
17. Serial Position	–	422	–	115–158	–
18. Two-person games	–	–	–	–	–
19. Two-person games	–	312	–	–	–

[a]General references:

Anderson, B. *The psychology experiment*. Belmont, Calif.: Wadsworth, 1966.

Hyman, R. *The nature of psychological inquiry*. Englewood Cliffs, New Jersey: Prentice-Hall, 1964.

[b]Key to table references A–E. Reprint numbers are listed for A and B; page numbers for C–E.

A. The Bobbs–Merrill reprint series in Psychology.

B. Scientific American Offprints.

C. Woodworth, R. S., & Schlosberg, H. *Experimental psychology*. New York: Holt, 1954.

D. Morgan, C. T., & King, R. A. *Introduction to psychology*. New York: McGraw-Hill, 1966.

E. Kendler, H. H. *Basic psychology*. (2nd ed.) New York: Appleton-Century-Crofts, 1968.

TABLE 2

Apparatus Requirements for Experiments in This Manual[a]

The experiments in this manual may be performed with the following apparatus

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Experiments 1–6

An operant conditioning apparatus is required; for example:

Operant conditioning kit No. 25
Scientific Prototype Mfg. Corp.
623 West 129th Street
New York, New York 10027

Experiments 7–9

A set of discrimination weights with the denominations indicated in the method section; for example:

Gilbert and Whipple weights, Model 1901
Lafayette Instrument Co.
North 26th Street and 52 By-Pass
Lafayette, Indiana

Experiment 11

A perimeter is required; for example:

Hand or Stand Perimeter, Schweigger Type
Lafayette Instrument Co.
North 26th Street and 52 By-Pass
Lafayette, Indiana

Experiment 12

A mirror training apparatus is required, for example:

Mirror Training apparatus No. 705
Lafayette Instrument Co.
North 26th and 52 By-Pass
Lafayette, Indiana

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[a]Stop watches, or sweep-second hand clocks in the experimental cubicles, would also be desirable.

EXPERIMENTS WITH ANIMAL BEHAVIOR

The human subject is a very complicated creature. He has typically had some eighteen or twenty years in an uncontrolled environment in which to learn strange and wondrous responses for the befuddlement of the experimenter. Not only has he learned to react differently from his fellow man, but also he has learned to meet simple situations with complex and unexpected responses that often get in the way of the behavior the psychologist wishes to study. Even if all goes smoothly, what the experimenter is observing may be a product more of a special and temporary human culture than of the biological nature of man. Moreover, many of the most significant and basic processes cannot be studied precisely because they are important, too important to interfere with for purposes of experimentation. The experimenter cannot be given the right to manipulate such crucial aspects of human existence or the authority needed to exercise adequate control over the conditions that might affect his subject's performance.

Faced with these problems, many psychologists, like their colleagues in the medical sciences, prefer to work with animal subjects. The laboratory animal can be reared under uniform, specifiable, and controllable conditions. He is more or less expendable and can be subjected to many procedures that could not be used with humans. And he is naive. In view of the similarity of biological structure and functioning within the mammalian range, at least, it is generally assumed that basic behavioral processes will likewise be much the same in man and animal. Continued observation seems to confirm this assumption. It should be recognized, of course, that there is more to human behavior than these elementary processes, in their simplest form, but the difference between the performance of the animal and that of the human, where it can be pinned down, provides valuable leads for distinguishing the inherent nature of man from the things he has acquired from the culture around him.

Aside from college students, rats are the organisms most commonly used for experimental work in psychology. They are small and can be cared for with a minimum of effort, space, and expense; they are hardy and tend to maintain better health than most other species; they are clean, friendly, and easy to deal with. Some students, particularly females, fear small, tame, clean, healthy rats brought up in the laboratory because they associate them with large, savage, dirty, and highly unsanitary rats seen in back alleys and garbage dumps. The name is the same, and there is obviously a genetic relationship, but it is also obvious that the two types of rats are very different in most respects. Above all, some students fear that the rats will bite them. Laboratory rats are not hostile, but like any animal they may indeed bite under certain circumstances. This sometimes happens when a human hand full of food is thrust into a cage of very hungry rats competing for the first morsel—one of the rats may be too hasty. It sometimes happens when rats go for periods of weeks or months without being handled—they are no longer accustomed to this interference and when next picked up may panic and snap. It sometimes happens when the rat becomes excited, for example, through being squeezed, dropped, chased around the floor. If a rat has escaped, and appears excited, it may be best to handle him with gloves. People who handle rats a great deal become accustomed to occasional bites under special circumstances and view them as a sort of initiation into a unique brotherhood. They know enough not to jerk the hand away when the rat bites, the result is no worse than a jab with a hypodermic needle; indeed, there is no preliminary anxiety since the bite is unexpected. As in the case of any puncture of the skin, the application of some form of disinfectant is a desirable precaution.

GENERAL PROCEDURES

The rat with which you and your laboratory partner will work will be either an albino (white) or a hooded (black and white) animal. These animals are procured for a dollar or two apiece from commercial supply houses. Males are preferred, since there is no estrous cycle to cause variations in the daily level of activity, but females usually give adequate stability of performance for the experiments to be conducted in this course. To avoid the birth of a litter in the middle of the experiment, the sexes are kept separate. Your rat will probably be about three months old by the time you begin to experiment with him. For the rat this age may be comparable to adolescence in the human. Some rats may reach a life span of two or three years under favorable conditions.

For several days before bringing the rat in for experimentation, a laboratory assistant has given him daily handling to accustom him to the disturbance of being picked up and carried across the room. Your rat has also been watered on a regular cycle, usually consisting of 1 hour of access to the water per day and 23 hours without water; the hour of drinking is ordinarily set for the time of day that comes immediately after the class session. The purpose of this deprivation cycle is to make the animal active during the experimental session and to ensure that he will be ready to drink when water is provided as a reward or reinforcement for his behavior. In special cases (e.g., in hot and humid weather), if it is feared that the animal will not be sufficiently active, your instructor may decide to let him go without water for 2 days, rather than the usual one.

It is possible that to another rat each rat looks different. But to the human experimenter a group of rats often looks very much like a large set of identical twins. In order to tell one rat from another, it is customary either to stain the back with some kind of dye or to punch holes or cut slits in the ear. A common procedure that can be used to identify four rats within the same living cage is to punch one in the right ear, another in the left, a third in both, and the fourth in neither. The rats can be listed or "named" in terms of the number of the cage and code letter R, L, B, or N, for the ear that is punched. One precaution, however, is very important. In picking up or returning your rat, *always* be sure to check the number of the cage. The cages may not be set down in the same order, and if you pick up 2N instead of 3N confusion may result; even more confusion may result if 2N and 3N are put back in the same cage.

When the time comes to pick up your rat and bring him back to the experimental box for training, you may ask for assistance from the instructor or his assistant if you are jittery, but remember that the rats that are used in a laboratory class have been accustomed in advance to being picked up, held, and set down by the human hand. This allows most of their early startle and struggle reactions to adapt out. You are much bigger than the rat, so let him know who is the master; but you are also strong enough to squash him, so you can afford to be gentle. Approach the rat slowly, with closed fist. Do not jerk extended fingers forward and backward in front of his face or pursue him frenziedly about the cage.

In an emergency the rat may be picked up by the tail without harm, but this may make him excited. Ordinarily, the rat is grasped from behind the shoulders, with his head and forelegs between the thumb and index finger and the rest of his body gripped in the palm of the hand. If he appears to be disturbed by his distance from the floor, you may wish to hold him close to your body or to place your hand or forearm under him for additional support. If a rat is sufficiently accustomed to human handling this usually works well, but if the rat is disturbed by being picked up this may result in cleaning bills; evacuation of the bowels or bladder is common when the rat is picked up for the first time.

During the experimental session, a number of factors can interfere with your rat's performance. An uncomfortable level of heat or humidity is one problem that it is difficult to do much about unless air conditioning has been provided. Other conditions, however, can be kept under control. Spilled water may lead to satiation unless the rat is quickly removed from the scene. Bright light tends to make him inactive; often he will curl up in a relatively dim corner to escape the light. Excessive noise, including loud talking between experimenters or persistent rapping on the cage is disturbing. The rat may react adversely to moving or jarring of his cage or to being prodded, shoved, or carried about more than is necessary. He is also a nonsmoker and has a sensitive nose.

Your rat should never be left unattended during the experimental session. There is no state of suspended animation, and the animal's behavior does not cease just because the experimenter's does. The behaving organism is always learning. There is only one experimental procedure outlined in this manual in which the experimenter does nothing for the rat, and that is the procedure for extinction, for eliminating the animal's response. The results may be disastrous to the experiment if this procedure is introduced, contrary to instructions, by the student. If procedures permit, it may be possible for one experimenter at a time to "take a break," but one experimenter, at least, should always remain with the animal.

Much the same reasoning holds for absences from class. If both experimenters are forced to miss class on the same day, part of the intended training is missing, and the rat will probably not be ready to go on to the next experimental procedure. The way to deal with this situation is for the student to make up the missed laboratory session.

BACKGROUND MATERIAL

Useful background material for the experiments to be performed in this part of the course may be found in the following references:

Holland, J. G., & Skinner, B. F. *The analysis of behavior: A program for self-instruction.* New York: McGraw-Hill, 1961.

Keller, F. S. *Learning: Reinforcement theory.* New York: Random House, 1954.

Keller, F. S., & Schoenfeld, W. N. *Principles of psychology.* New York: Appleton-Century-Crofts, 1950.

Logan, F. A., & Wagner, A. R. *Reward and punishment.* Boston: Allyn & Bacon, 1965.

Reynolds, G. S. *A primer of operant conditioning.* Glenview, Ill.: Scott, Foresman, 1968.

Sidman, M. *Tactics of scientific research: Evaluating experimental data in psychology.* New York: Basic Books, 1960.

Skinner, B. F. *Science and human behavior.* New York: Macmillan, 1953.

CONDITIONING THE RAT

Once our rats have learned to press the bar regularly, we will be ready to carry on formal experiments in which we determine the effects of various conditions and procedures on the rate and distribution of pressing. We will have achieved a stable starting point that is much the same for all animals. Before the rats have been conditioned, however, there is a great deal of variability in the behavior with which we have to work. Moreover, the most successful methods are difficult to standardize because we are dealing with a great variety of responses that are difficult to classify and count, and it is therefore hard to work out exact rules. The rules that have been worked out are often interpreted differently by different people. The result is that the original training is the most difficult procedure for the student to handle and involves the greatest variation in performance among the different animals.

The usual training sequence involves three main steps, although some instructors may want to combine the first two steps. The first step is to familiarize the animal with the bar-pressing box (and the student with the rat) and to let him learn to drink from the dipper. The second step is to train the animal to approach the dipper promptly whenever the experimenter wishes to deliver a reinforcement. The third step is to train the rat to make the final response of pressing the bar.

1. Familiarization. The bar is removed from the box. The tank is filled with enough water to make it easy to load the dipper. One of the experimental partners is given the rat and allowed to bring him to the conditioning box. (Be sure you know how to hold him.) The rat is put in the box and allowed to drink as many dipper loads of water as he will drink within the time available. If he drinks quite readily, it is a good idea to go on with Step 2, dipper training, before he becomes too thoroughly committed to the response of crouching over the dipper, which may interfere with his learning of other responses later. On the other hand, it should not be assumed that the rat will immediately drink from the dipper. In some cases he will do so, but in others he may show an annoying ability to ignore water that is literally right under his nose. There is nothing to do but wait. Some students think they are better rat trainers than the instructor; this is a rash assumption. For example, pushing the rat to the dipper may so disturb him as to make him almost impossible to condition. Most other forms of interference are likely to do more harm than good. Patience is a great virtue in the fledgling experimenter. In any case, the student has an opportunity to observe some of the typical actions of the rat in the box so that he has some idea of what to expect in later sessions.

2. Dipper training. In this session, the rat learns to approach the dipper and drink whenever the experimenter delivers water. The student should operate the dipper with a distinctly audible sound, so that a clear signal is provided. On the other hand, the rat should not be frightened away from the dipper by the violence of the action. At first the dipper is operated while the rat is still close by. Care should be taken, however, to avoid catching the rat's tongue, as this may cause him to avoid the dipper. If the rat drinks immediately each time the dipper is operated, the next step is to let him learn that there is no water in the dipper without the sound. If the rat is unusually persistent at pawing or biting the empty dipper, it may be necessary to lower it out of his reach between times. Finally, the rat can be trained to approach the dipper from gradually increasing distances, particularly from the neighborhood of the bar, by waiting until he is a little farther away before operating the dipper. At this stage, care should be taken to avoid conditioning a "superstitious" response that might interfere with the conditioning of bar pressing. For example, the rat should not be allowed to learn a regular sequence of moving away from the bar to a particular spot and immediately returning; he should be allowed to vary his actions and he should be forced to wait for the sound before he approaches. If a rat that has been active and has learned well begins to slow down after a hundred or two hundred drinks, it may be that his thirst is diminishing, that is, that he is "satiating." In this case, check with your instructor, who may wish to take the rat back to his living cage.

3. *Conditioning.* Many rats will press the bar spontaneously before they are specifically trained to do so. In some cases, immediate reinforcement of these responses will be sufficient to begin the conditioning process. Other rats fail to press the bar even when exploring the walls of the cage all around them. In cases like this, it is necessary to use a process of gradual approximation. There are a number of stages that may be discerned between complete inactivity—which is the most difficult performance with which to deal—and actual pressing of the bar. If the rat is inactive or hovers about the dipper, he must be reinforced for moving about. Next, he may be reinforced for approaching the vicinity of the bar. If he will approach the bar rather closely, reinforcement can then be given for such reasons as moving toward the bar, placing the paws on the wall of the box above the bar, pawing motions, or touching the bar—anything that is similar to pressing or that is likely to lead to pressing. A slight movement of the bar may be reinforced. Finally, reinforcement is given only for complete presses, in which the bar is pushed all the way down. In moving through these successive approximations to bar pressing, two general rules must be kept in mind: First, water must always be given some of the time for *some* behavior within the rat's current range of performance. If he goes too long without water, he may cease doing even that. On the other hand, if he is maintaining one item of performance at a high level of activity, it is possible to let it go unreinforced a few times while waiting for an opportunity to reinforce something better. The second rule is not to reinforce the animal so often for something that he is already doing that he has no opportunity to vary his performance and come up

with something better. Too frequent reinforcement also uses up too quickly the number of reinforcements available in a given session before the rat begins to satiate. Since one rule says not to withhold reinforcement too long and the other rule says not to reinforce too often, it is evident that some artistry is required to maintain the best balance between these extremes. Watch your rat closely and let his behavior be your guide. A further caution is that delayed reinforcement is not very effective; when you see something you want to reinforce, operate the dipper as fast as you can, and hope, too, that the rat promptly approaches it. Sometimes a dipper-trained rat can be brought over by repeated sounding of the dipper; if he delays too long, however, it may be well to lower the dipper again, so that he does not get a "free drink" (that is, a drink for nothing).

The original conditioning of the bar-pressing response can be tedious and frustrating, but there are few, if any, rats that will not learn. Do not be led by your eagerness for immediate success to violate the rules and slow down your rat's progress. If something has gone wrong on the first conditioning session, often the difficulty (e.g., lethargy, emotional reaction, satiation) disappears when a second session is given.

4. Results. Since the criterion for what behavior will be accepted as a satisfactory response varies during approximation training, no very systematic record of the change in performance can be obtained. However, for purely practical purposes, it is often helpful to know how active the animal has been, how many reinforcements he has been given, how many times he has actually pressed the bar, and so on. A data sheet has, therefore, been provided for keeping a rough record of what the rat has been doing. A sample cumulative record has also been provided to illustrate typical conditioning under good conditions. The procedure for constructing such a curve is described in the section on treatment of data in Experiment 1.

Data Sheet

Conditioning the Rat

Experimenter ______________

Partner ______________

Reinforcements for:

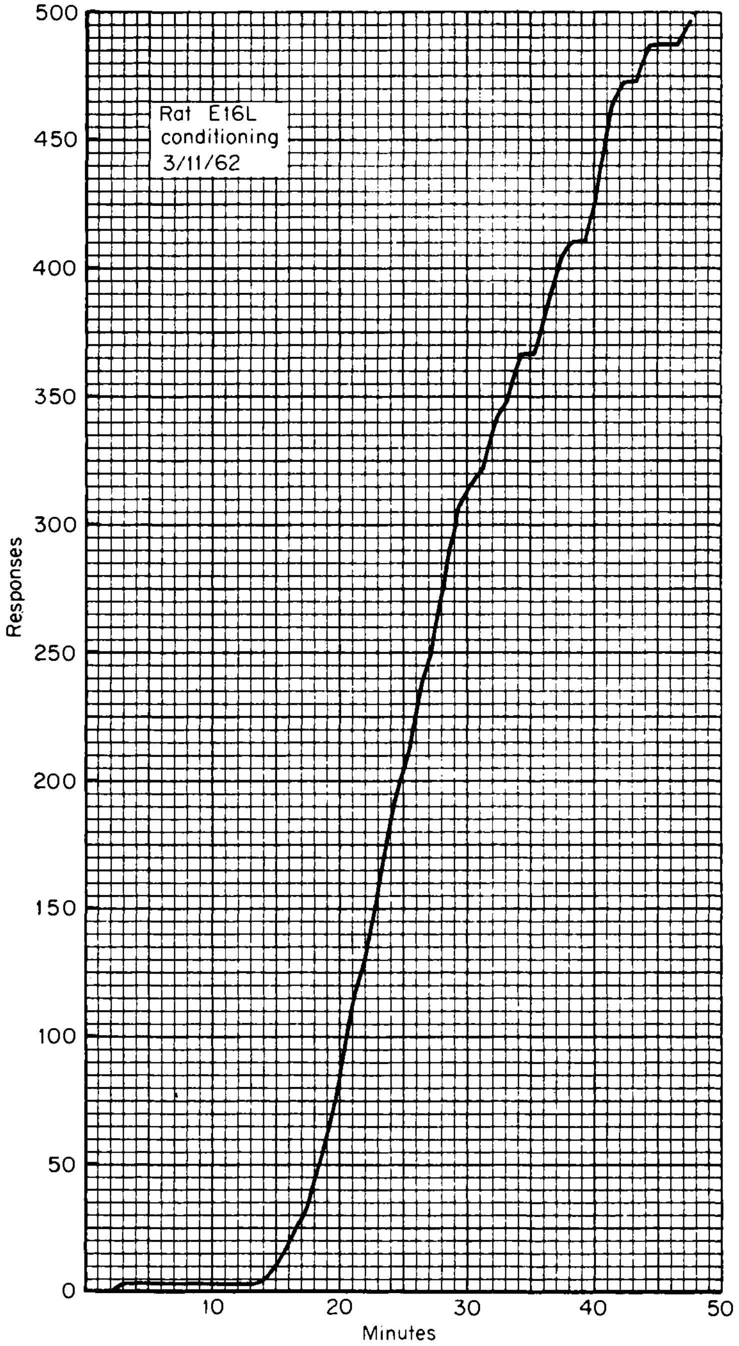
Rat ________ Cubicle ________

Minute	Presses	Minute	Presses	Minute	Presses	Minute	Presses
1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

(*Continued*)

Data Sheet (*Continued*)

Minute	Presses	Minute	Presses	Minute	Presses	Minute	Presses
101		126		151		176	
102		127		152		177	
103		128		153		178	
104		129		154		179	
105		130		155		180	
106		131		156		181	
107		132		157		182	
108		133		158		183	
109		134		159		184	
110		135		160		185	
111		136		161		186	
112		137		162		187	
113		138		163		188	
114		139		164		189	
115		140		165		190	
116		141		166		191	
117		142		167		192	
118		143		168		193	
119		144		169		194	
120		145		170		195	
121		146		171		196	
122		147		172		197	
123		148		173		198	
124		149		174		199	
125		150		175		200	


Rat E16L
conditioning
3/11/62
Responses
500
450
400
350
300
250
200
150
100
50
0
10
20
30
40
50
Minutes

EXPERIMENT

1 EXTINCTION AND SPONTANEOUS RECOVERY

PROBLEM

When the reinforcement that was used to condition a response is no longer delivered, the rate of responding suffers a gradual decline until the animal is giving about the same number of responses as he was before conditioning. This method of reducing or eliminating the response is known as *experimental extinction.* If the animal is then removed from the experimental box for a time ranging from several minutes to several days, he responds more frequently at the beginning of the new session than he did at the end of the old, even though no further conditioning has been given. The increase in rate of response without further reinforcement is called *spontaneous recovery.* In this experiment the student will permit the extinction of the bar-pressing response and observe whether spontaneous recovery occurs.

PROCEDURE

At the beginning of the session the rat is given 50 more reinforcements for bar pressing, to make sure that the response is thoroughly established. Then reinforcement is withheld for a 20-minute period of extinction. At the next meeting of the class, the animal will be placed in the box for another 5 minutes without reinforcement.

CONTROLS

Although quite elementary, the precautions taken to reduce the influence of extraneous variables on the results of this experiment are worth noting. Samples of the animal's performance are taken before and after the passage of a period of time in which the animal is outside of the experimental situation. Note that the same individual is used in both cases, so that no individual differences enter into the comparison, that the apparatus, conditions of deprivation, and time of day are the same, and that no reinforcement is given in either case. The only systematic difference is that the animal has been taken out of the experimental situation and returned after a period of time. Time, however, is not a basic or unitary variable in its own right, but a dimension of other variables. The passage of time permits things to happen. The animal continues to live and to function—to eat, drink, run, look, listen, etc.—even though he is in his home cage rather than in the conditioning box. Thus, time may be viewed as a complex package or bundle of more elementary variables which would be very difficult to separate in such a way that we could trace the individual effects. It is also possible that the experimental situation has changed in some degree with the passage of time or that the animal's behavior at the beginning of a new session is affected by his immediate previous experience in being transported to the conditioning box and placed inside it.

RESULTS

The number of responses in each minute of the experimental session should be tallied and cumulated. A cumulative total is calculated by adding the number of responses in each successive minute to the total number of responses obtained up to that time. For example, if the rat makes two responses in each of the first 3 minutes of the session, his cumulative totals for these minutes will be 2, 4, and 6, respectively. (In sports, a team's score is a cumulative record of the points it has made.) The resulting values should be plotted on a sheet of graph paper, using the vertical dimension for the cumulative totals and the horizontal dimension for time in minutes. Choose an appropriate scale for a sensible looking graph. Your cumulative graph will then be a rough approximation of the sort of curve that is drawn automatically by the cumulative recorder in the research laboratory. While it may not show all the details, the hand-drawn graph, like the automatic record, indicates the rate of responding during any part of the experiment by the slope of the line, and the total number of responses by its height. Your cumulative graph of the process of extinction should show a gradual (but sometimes a sudden) decline in slope. The curve always rises, however, or remains horizontal; if it begins to drop, you are doing something wrong.

Also find the total number of responses in the last 5 minutes of the original extinction session and the total number of responses in the 5 minutes of spontaneous recovery at the beginning of the following session.

DISCUSSION

Is this experiment adequate to support the conclusion that the increase in responding, from the end of extinction to the first 5 minutes after the rest, was due to the rest period alone? For example, has the subject been handled equally recently at the time of the two testing periods? Has he received water equally recently? How would the procedure have to be altered to allow one to make that conclusion?

Data Sheet

Experiment 1:

Experimenter ______________________

Partner ______________________

Extinction and Spontaneous Recovery

Rat ______________________

Extinction

Min.	Resp.	Cum. Resp.
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

(Continued)

Spontaneous Recovery

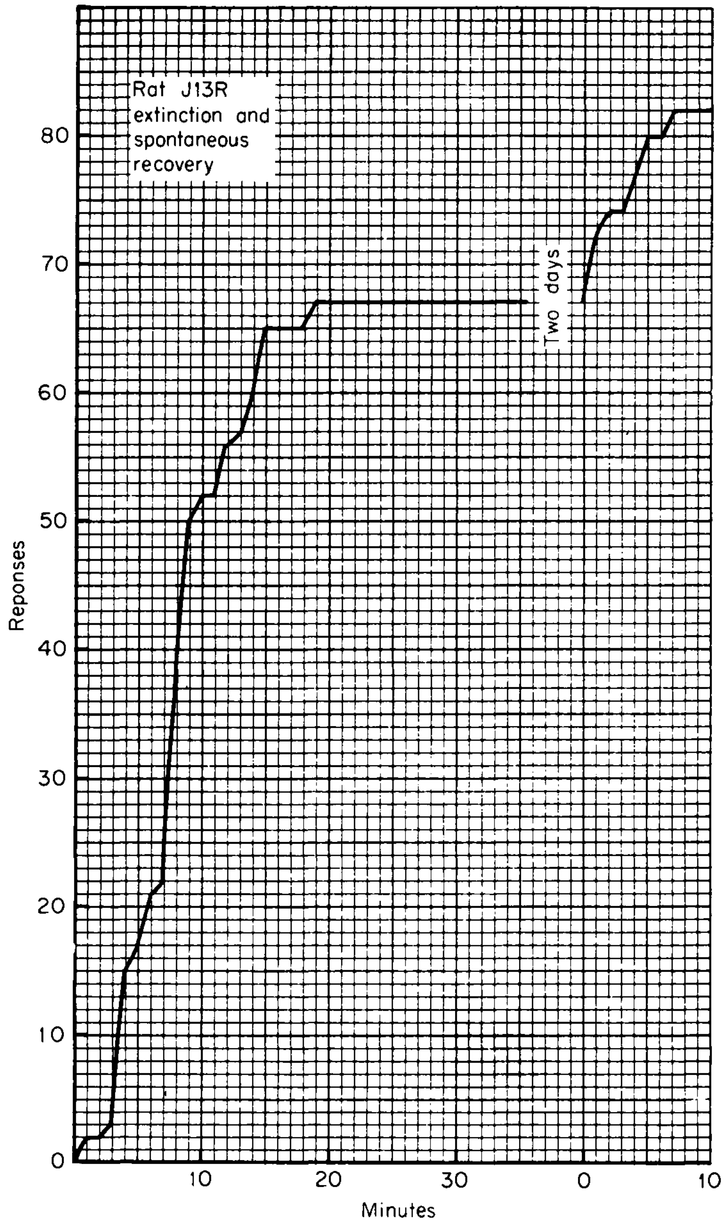
Min.	Resp.	Cum. Resp.
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Data Sheet (*Continued*)

Min.	Resp.	Cum. Resp.
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		

Total responses in 5-minute test period at end of extinction ____________

Total responses in 5-minute test period for spontaneous recovery ________


Rat J13R
extinction and
spontaneous
recovery
Two days
Reponses
0
10
20
30
40
50
60
70
80
10
20
30
0
10
Minutes

EXPERIMENT

2 DISCRIMINATION TRAINING

PROBLEM

In a natural setting the living organism must learn not only to make a certain response, but when or under what conditions to make it. This is the problem of relating the behavior to the environmental situation, of placing the response under the control of discriminative stimuli. The behavior of pressing the bar can be brought under the control of stimulus conditions by a very simple extension of the basic principles of conditioning and extinction demonstrated in previous laboratory work. In one stimulus situation, the S^D, pressing the bar is reinforced; in the absence of this stimulus, the S^Δ, pressing is not reinforced. With this procedure, the rat maintains a high rate under one condition, but drops to a lower rate under the other. Note that you have already conducted some discrimination training during dipper training. The rat learned to approach the dipper when the sound was heard, but not to approach when there was no sound. But now we will conduct discrimination training with a well-defined and easily recorded response so that we can see more clearly what is happening.

PROCEDURE

The laboratory shall be darkened as much as possible, so as to establish a reasonable contrast between the levels of illumination produced when the light in the experimental chamber is turned on or off. The rats will be assigned to one of three experimental conditions.

I. The light will be turned on and off in alternation for periods of 1 minute each. During periods when the light is on, bar pressing will be reinforced. During periods when the light is off, no reinforcement will be given. As in the previous experiment the performance of the same animal is compared under two different conditions. In one respect the control is a little closer than in the previous experiment, since responding in the light and responding in the dark are sampled at almost the same time, i.e., in alternation. There is no opportunity for day to day variations in the animal's health or level of activity to influence the comparison. An even more refined procedure would be to present periods of light and darkness in random order rather than single alternation, thereby preventing the animal from employing a temporal cue rather than the one of level of illumination.

II. It is possible that light and darkness have some inherent effect on the animal's performance which is independent of their relationship to the delivery of water. If it were the case that the rat is more (or less) active in the darkness than in the light, this would bias the results. As a control, we can switch conditions for half of the animals, so that they receive reinforcement in the dark, but no reinforcement in the light. Thus, by *counterbalancing* the pairing of light and darkness with reinforcement and nonreinforcement, we can minimize one source of possible bias.

III. In order to assert that the light and darkness were serving as discriminative stimuli, and not some other cues, we must institute additional control. The comparison in Groups I and II may be affected by the water serving not only as a reinforcer, but also as a discriminative stimulus. The receipt of water usually indicates that more water is forthcoming, just as the presence of light (or dark) indicates that water is forthcoming. Therefore, the animals in this group shall receive conditions identical to those for Group I except that no change in illumination level will be made, the light remaining on at all times. A better, though more arduous, procedure would be to allow the illumination to vary from bright to dark in a haphazard order *uncorrelated* with the alternating presence and absence of reinforcement.

RESULTS

The instructor may wish to continue the experiment for two or three class sessions, to provide enough time for a clear difference in behavior to develop. Experimenters should record the number of responses in each minute of light and each minute of darkness. Then, for each 2-minute block of time, the proportion: S^D/total responses to both S^D and S^Δ, should be computed.

REFERENCE

Riley, D. A. *Discrimination learning.* Boston: Allyn & Bacon, 1968.

Data Sheet

Experiment 2:

Experimenter ______________________

Partner ______________________

Discrimination Training

Rat ______________________

	S^D	S^Δ	$S^D + S^\Delta$	$\frac{S^D}{S^D + S^\Delta}$		S^D	S^Δ	$S^D + S^\Delta$	$\frac{S^D}{S^D + S^\Delta}$		S^D	S^Δ	$S^D + S^\Delta$	$\frac{S^D}{S^D + S^\Delta}$
1					26					51				
2					27					52				
3					28					53				
4					29					54				
5					30					55				
6					31					56				
7					32					57				
8					33					58				
9					34					59				
10					35					60				
11					36					61				
12					37					62				
13					38					63				
14					39					64				
15					40					65				
16					41					66				
17					42					67				
18					43					68				
19					44					69				
20					45					70				
21					46					71				
22					47					72				
23					48					73				
24					49					74				
25					50					75				

(*Continued*)

Data Sheet (*Continued*)

	S^D	S^Δ	$S^D + S^\Delta$	$\frac{S^D}{S^D + S^\Delta}$		S^D	S^Δ	$S^D + S^\Delta$	$\frac{S^D}{S^D + S^\Delta}$		S^D	S^Δ	$S^D + S^\Delta$	$\frac{S^D}{S^D + S^\Delta}$
76					101					126				
77					102					127				
78					103					128				
79					104					129				
80					105					130				
81					106					131				
82					107					132				
83					108					133				
84					109					134				
85					110					135				
86					111					136				
87					112					137				
88					113					138				
89					114					139				
90					115					140				
91					116					141				
92					117					142				
93					118					143				
94					119					144				
95					120					145				
96					121					146				
97					122					147				
98					123					148				
99					124					149				
100					125					150				

EXPERIMENT

3 SECONDARY REINFORCEMENT

PROBLEM

It is clear that not all our behavior is directly reinforced with food, water, sex, or other biologically innate reinforcers. Part of the explanation may be that occasional reinforcement of our behavior is enough to keep us going. Another reason that has been suggested is that many kinds of happenings not originally or inherently reinforcing may become reinforcing under certain conditions. This experiment is a study of the effectiveness of a stimulus that has *acquired* reinforcing value for the rat. During dipper training and conditioning, the sound of the dipper being operated was paired with the receipt of water itself, an inherent or *primary* reinforcer. The sound served as a discriminative stimulus for approach to the dipper. Now we will conduct a test to determine whether it has also become a *secondary reinforcer* for bar pressing.

PROCEDURE

The class session will be divided into eight 5-minute periods, and the rat will alternately be conditioned during one period and extinguished during the next. The conditioning restores his response to much the same level each time, and the subsequent extinction tests the number of responses he will give. During the first and last of the extinction periods the dipper is operated each time the rat presses, with the usual sound, and then retracted before he gets to drink. (Be careful not to splash water around the dipper opening or some primary reinforcement may be confounded with the secondary!) During the middle two extinction periods no sound is given. The reinforcement provided to the animal during the eight successive periods may then be listed as follows:

1. water
2. sound
3. water
4. nothing
5. water
6. nothing
7. water
8. sound

One of the most common problems faced in psychological experimentation is separating the effects of the conditions to be investigated from the effects of time or sequence. This experiment illustrates one method for dealing with the problem. Although the response is reconditioned (periods one, three, five, seven) between each test period (two, four, six, eight), there would probably be some consistent upward or downward trend in the performance during successive test periods even if the procedures were all the same. So that neither the procedure in which the sound of the dipper is used nor the procedure without the sound of the dipper will be systematically favored by this trend, the procedure with sound is presented first during the first pair of tests (two, four) and the procedure without sound is presented first during the second pair of tests (six, eight). It is assumed that the advantage gained at one point in the sequence is more or less balanced or canceled out by the loss incurred at the other point in the sequence.

RESULTS

Count the number of responses in each extinction period. Compare the total for the two periods with sound of the dipper with the total for the two periods in which nothing was given.

DISCUSSION

The above procedure does not provide the most appropriate test of the secondary reinforcement property of the dipper sound, since the reinforcing potential of the sound is being tested by its ability to sustain bar pressing in the absence of water rather than through its ability to produce *new* learning. It is possible that the dipper sound functions primarily as a discriminative stimulus for further bar pressing, since the animal was reinforced during acquisition for bar presses which followed just after the last dipper sound and water presentation.

For an improved test of secondary reinforcement one would employ the sound of the dipper as a reinforcement for some new behavior, such as making contact with an object placed in the bottom of the conditioning chamber. During this test the bar would be absent. If object contacts followed by dipper soundings were to show increased frequency, secondary reinforcement by the sound would be more firmly established. It is entirely possible that the sound employed was a reinforcement by its own right, without being paired with water delivery. How would such a possibility bear on the conclusion that we have demonstrated secondary reinforcement? What changes in the design of this experiment would be needed to control for this possibility?

REFERENCES

Kelleher, R. T., & Golub, L. R. A review of positive conditioned reinforcement. *Journal of Experimental Analysis of Behavior,* 1962, Supplement to Vol. **5**, 543-597.

Myers, J. L. Secondary reinforcement: A review of recent experimentation. *Psychological Bulletin,* 1958, **55**, 284-301.

Data Sheet

Experiment 3:

Experimenter ______________________

Partner ______________________

Rat ______________________

Secondary Reinforcement

Period	Water
1	
3	
5	
7	
Total	
Average	

Period	Sound
2	
8	
Total	
Average	

Period	Nothing
4	
6	
Total	
Average	

SCHEDULES OF REINFORCEMENT: INTRODUCTION

The experiment on simple conditioning demonstrated the principle of reinforcement, that is, the probability (or rate) of an operant response (e.g., bar press) is increased when that response is selectively followed by a reinforcement (e.g., water). We may describe this experimental situation by saying that the reinforcement is contingent upon the animal's response (bar press), each and every response procuring a reinforcement. This contingency of reinforcement and response is an independent variable, and may be varied in numerous ways by the experimenter. Such variations in reinforcement contingencies are known as schedules of reinforcement.

1. CRF. In the simplest contingency, the animal receives a reinforcement for every response, thus, the schedule is one of continuous reinforcement and is usually referred to as a CRF schedule. The abbreviation stands for *C*ontinuous *R*ein*F*orcement.

2. Ratio. The reinforcement contingency may be altered so that the animal is required to make more than one response in order to receive a single reinforcement. The contingency may be set to reward every other response, every third response, every tenth response, or in general every *N*th response. The outstanding feature of this type of schedule is that the animal must make a fixed number of responses in order to receive a single reinforcement, or in other words, there is a definite ratio of unreinforced to reinforced responses. Such a schedule is called an FR schedule, the abbreviation standing for *F*ixed *R*atio. A fixed ratio schedule is usually designated by placing the value of the ratio after the letters "FR." Thus FR-12 reads "Fixed Ratio twelve" and means that the animal receives a reinforcement for every twelfth response, eleven responses going unrewarded. On this schedule, animals show a pause after each reinforcement, and then a "burst" of responses as the animal "runs off" the schedule to receive the next reinforcement.

Another ratio contingency involves "mixing up" different ratios in the same schedule so that each reinforced response is preceded not by a fixed number of unreinforced responses, but by a variable number of unreinforced responses. Such a schedule, for example, might have 3 unreinforced responses to the first reinforcement, 10 to the second reinforcement, 5 to the third, 7 to the fourth, and so on. The chief characteristic of this type of schedule is that each reinforcement is preceded by a variable number of unreinforced responses and is accordingly called a VR schedule, standing for *V*ariable *R*atio schedule. While the ratio varies from reinforcement to reinforcement, we can specify the schedule by the average or mean value of the several ratios employed. Thus "VR-10" reads "Variable Ratio-ten" and means that on the average the different ratios in the schedule reinforce every tenth response, some ratios being longer and some shorter than ten.

3. Interval. In ratio schedules, the contingency of reinforcement depends on the number of responses the animal makes. On interval schedules, the reinforcement contingency is dependent upon time and independent of the number of responses made by the animal. On the simplest interval schedule, the experimenter measures some fixed interval of time, say 1 minute, since the last reinforced response and reinforces the first response that occurs after this interval has elapsed. From this reinforced response the experimenter again measures out a 1-minute interval and again rewards the first response to occur after the interval, and so on. No responses are rewarded during the interval, and the animal must wait at least 1 minute after each reinforced response in order to obtain another reward. In this schedule the time interval is fixed and so it is called an FI schedule, standing for *F*ixed *I*nterval schedule. FI schedules are designated by the abbreviation FI followed by the interval, e.g., FI-1 min.

A second type of interval schedule is the VI schedule, standing for *V*ariable *I*nterval, which is analogous to the VR schedule. Here the interval elapsed since the last reinforcement to the next reinforcement is variable rather than fixed; again as for the VR schedule, we designate the variable interval schedule by the average interval. Thus VI-2 min. reads "Variable Interval two minutes," meaning that the average interval is 2 minutes, some intervals being longer and some shorter than this mean value.

4. Rate. In addition to the four basic schedules of FR, VR, FI, and VI, we can adjust the reinforcement contingency so that it depends upon the rate of the animal's responding. We can, for example, provide reinforcement only after a fixed pause during which no responses are made, say an interval of 1 minute, and reinforce the first response to occur after this interval has elapsed. This differs from the FI schedule in that here the animal must make no responses during the interval. If the animal does respond, we reset our watch and wait for another minute during which no response occurs, reinforcement being provided for the next succeeding response, and another interval of 1 minute must then elapse before reinforcement is again available. On such a schedule an animal will obtain the greatest amount of

reinforcement by responding at a very low rate, in fact, at a rate of one response per interval. This schedule is called a DRL schedule, standing for *D*ifferential *R*einforcement of *L*ow rates and is designated DRL followed by the interval, e.g., DRL-1 minute.

A schedule that is just the opposite of DRL is the DRH schedule, which stands for *D*ifferential *R*einforcement of *H*igh rates. On DRH the animal is rewarded only if one response follows another by a fixed, short interval. The animal must then respond rapidly to receive a reward, and this contingency leads to high rates of responding.

5. Other schedules. Much more complicated schedules may be obtained by combinations of the simpler schedules. Among the more complex schedules are:

Tandem schedules–a single reinforcement is provided for completing two different schedules in succession.

Multiple schedules–two schedules alternate with a stimulus (S^D) marking the change from one schedule to the other.

Chained schedules–responding on one schedule produces a stimulus (S^D) which indicates that a second schedule is now in effect, the second schedule being the one that provides primary reinforcement.

Concurrent schedules–two different schedules are operating (i.e., providing reinforcement) at the same time.

Figure 1 presents some typical records obtained for several different schedules.

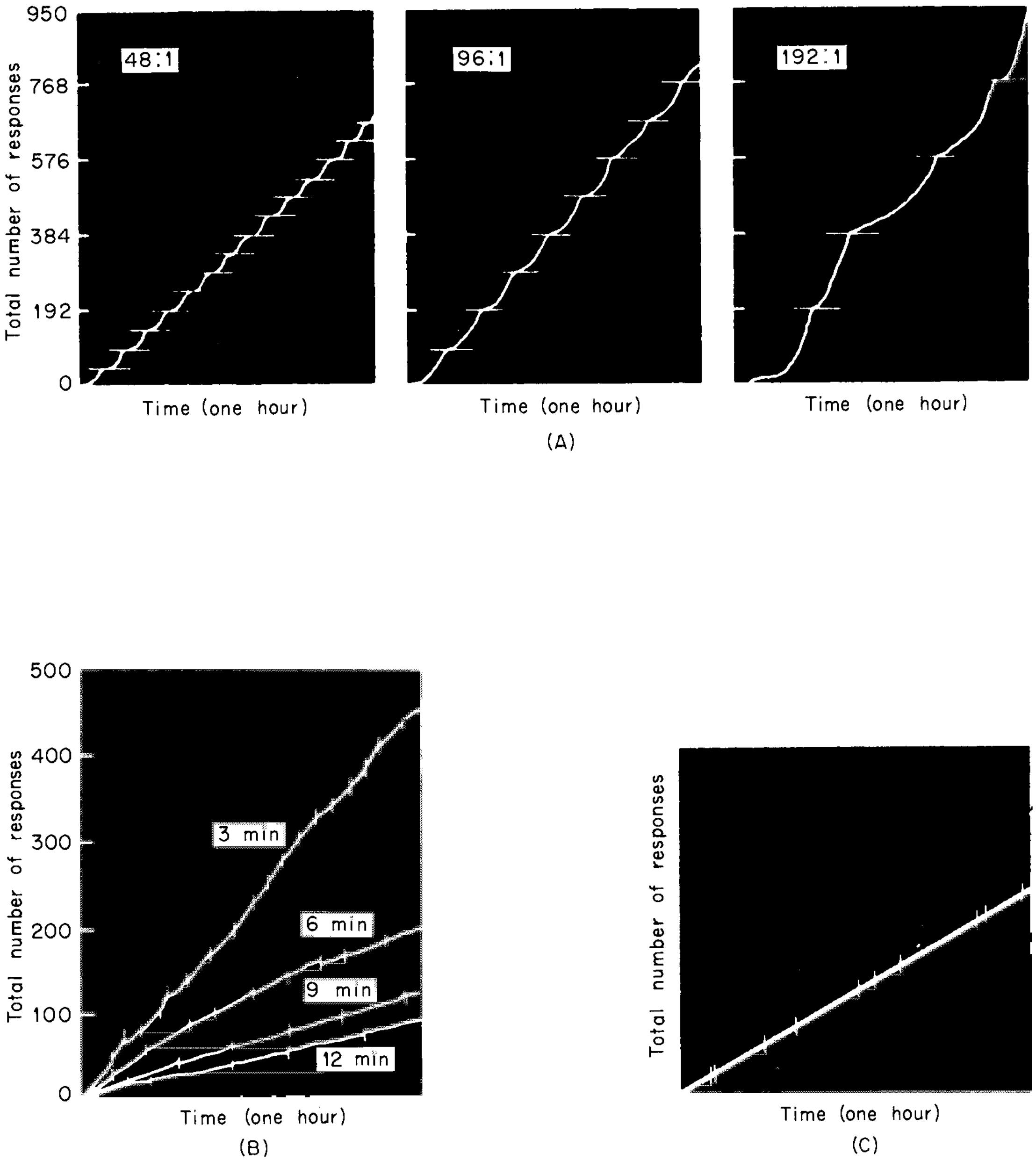


Fig 1 Typical cumulative records for three types of reinforcement schedules: (A) fixed ratio reinforcement at three different ratios; (B) fixed interval reinforcement at four different intervals; and (C) variable interval reinforcement. Vertical lines indicate delivery of reinforcement.

EXPERIMENT

4 RESPONSE RATE AND SCHEDULES OF REINFORCEMENT

PROBLEM

The purpose of this experiment is to compare the rate of responding on different schedules of reinforcement.

PROCEDURE

All animals should be previously conditioned to bar-press for water on a CRF schedule and should be water deprived at the start of the experiment. Your laboratory instructor will divide the class into five groups and assign one of the following schedules to each group:

CRF, FR-10, VR-10, FI-50 sec., VI-50 sec.

For the ratio groups, begin by introducing only a few nonreinforced trials at the start, say every other one, then gradually increase the number until the desired ratio is achieved. Remember, introduce nonreinforced trials gradually, allowing your animal to achieve a fairly steady rate for each new increase. Giving too many nonreinforced trials too soon will result in extinction.

Similar precautions apply to the interval groups. Begin with short intervals, say 10 seconds, and gradually introduce longer ones, allowing your animal to achieve a steady rate for each new increase in interval. Long intervals introduced too soon will result in extinction.

The variable schedules for the ratio and interval groups may be obtained from the table of random numbers (Appendix B) as follows.

VR-10. To obtain successive variable ratios, begin with the first column in the random number table and sum the pairs of digits to obtain the value of the ratio; for example:

Random No.	Summed pair	Ratio value
73	7 + 3	10
52	5 + 2	7
39	3 + 9	12

and so on. Let 00 be equal to a ratio value of 20.

VI-50 sec. Let each pair of random numbers be equal to the number of seconds in successive intervals. Thus, reading down column 1 from the table of random numbers, the animal is reinforced for the first response to occur after 73 seconds, the next response to occur after 52 seconds, the next after 39 seconds, and so on. Let 00 be equal to 100 seconds. Remember that each interval is timed from the last reinforced response. The *next* response to occur *after* the interval has elapsed is reinforced, and the timing of the next interval begins.

RESULTS

When your animal has achieved a steady rate of responding on the schedule you have been assigned, count the number of responses over a 15-minute period. From the data of all groups, make histograms of the mean rate of responding for each of the schedules.

EXPERIMENT

5 THE PARTIAL REINFORCEMENT EFFECT IN EXTINCTION

PROBLEM

Schedules of reinforcement, other than CRF, usually involve more than one response per reinforcement, hence, reinforcement is discontinuous with respect to responding. Another way of saying this is that the animal receives partial rather than total reinforcement for each response. One of the most interesting effects of partial reinforcement is that it produces a very high resistance to extinction (continued responding after primary reinforcement has been discontinued), much higher in fact than continuous reinforcement. This is known as the partial reinforcement effect and is of considerable interest because it presents the following problem: Since resistance to extinction is one of the performance measures often used to indicate the strength of learning, and since reinforcement strengthens (makes more probable) an operant response, how is it possible that giving less (partial) reinforcement leads to a greater resistance to extinction (more learning) than giving more (continuous) reinforcement? In the present experiment you will compare the resistance to extinction following responding on each of five different schedules of reinforcement.

PROCEDURE

For the first part of the experiment the procedure is identical to the procedure for Experiment 4 (Response Rate and Schedules of Reinforcement). After your animal has been shaped to the schedule and has been responding at a steady rate for 30 minutes, withdraw the water cup (thus starting extinction), note the time, and begin counting the number of responses. Extinguish your animal to a criterion of no response for a consecutive 2-minute period.

RESULTS

For all groups, compute the mean total number of responses to extinction and the mean rate of responding during extinction.

REFERENCE

Lewis, D. R. Partial reinforcement: A selective review of the literature since 1950. *Psychological Bulletin,* 1960, **57**, 1-28.

EXPERIMENT

6 MOTIVATION

PROBLEM

Psychologists define motivation (or drive) in terms of the operations used to establish it; since the definition amounts to a description of these operations, it is called an operational definition. For example, we define the thirst drive in terms of number of hours of water deprivation, that is, in terms of the operation of depriving the animal of water. This thirst drive, defined in this way, is an independent variable, and in the present experiment we will investigate the effect of this variable on response rate.

PROCEDURE

The class will be divided into 5 groups. For the first hour all animals will receive reinforcement on FI-1 min. schedule (see schedules of reinforcement, page 35). Use the first half hour to shape your animal to this schedule. For the second half hour, when the animal is responding at a steady rate, count the total number of responses. At the end of this period, all animals are removed from the cages and allowed to drink the following amounts of water:

Group	Amount of water (ml)
1	None
2	2
3	4
4	6
5	8

When the animals have finished drinking, they are returned to the apparatus and given FI-1 min. reinforcement for another 30 minutes, during which the total number of responses is again recorded.

RESULTS

Make a graph comparing the rates of responding for each group both before and after free water consumption.

EXPERIMENT

7 THE DIFFERENCE THRESHOLD FOR WEIGHT

PROBLEM

One of the earliest areas of psychological investigation was called psychophysics. Measurements are obtained which are indices of the subject's ability to discriminate some aspect of stimulation. One question was concerned with magnitude along some stimulus dimension required for the subject to respond. The *absolute threshold* for a tone, for instance, would be that intensity required for the subject to report that he hears the tone. Another question was concerned with *difference thresholds.* How much do two stimuli have to differ so that the subject can reliably report a difference?

The techniques developed to investigate these problems are of three basic types. In the *Method of Limits* the experimenter varies the value of some stimulus by small steps in a systematic progression from low to high and from high to low. Thus in determining the auditory absolute threshold the tone would be gradually increased until the subject reported hearing it. Then the tone would be gradually decreased until the subject no longer reported it. In the *Method of Average Error* the subject adjusts the value of a comparison stimulus until he judges it to be equal to a standard stimulus. After repetitions of this adjustment the average and variability of his errors indicate the efficiency of his discrimination. In the *Method of Constant Stimuli* the experimenter presents a variable stimulus many times in an unsystematic order. The latter method will be illustrated in the present experiment.

The difference threshold has often been called the "just-noticeable-difference." Scales have been devised using just-noticeable-differences (JNDs) as units. The present experiment will investigate the relationship between size of the difference threshold and level of stimulation used in the determination of the threshold.

Part A

APPARATUS

Two sets of weights will be used, one from 75 to 125 grams, and the other from 175 to 225 grams. Only one set will be used at a time: The first set will be exchanged for the second. The blindfold is composed of two cotton pads (Coets) to go over the eyes and a strip of gauze to tie them in place.

PROCEDURE

The Method of Constant Stimuli will be used. On a given trial, the subject is given the standard weight (middle value in the series), which he grasps from above with his thumb and first two fingers. Keeping his elbow on the table, he lifts it off the table for about 5 seconds, moving it up and down to judge the weight. Five seconds later he is given one of the comparison stimuli which he lifts in the same way. During the ensuing 5 seconds between trials he reports whether he considers the comparison weight to have been heavier or lighter than the standard. The experimenter records this with H or L.

First the subject is blindfolded and instructed how to lift the weights. Then he is given two practice trials with the heaviest weight in the series and two with the lightest. Finally he is run through the entire series of weights (including the standard, which also serves as a comparison weight), in random order, ten times. After the subject has finished with one set of weights, he should be given a rest period of at least 10 minutes, since the procedure is somewhat tedious and may lead to a reduction in the care with which he makes his judgments. Then, if the second set is available, the procedure is repeated with a new set of weights. Only one subject need be run in a single class period.

RESULTS

Tally the number of H's in each column for each set of weights. If the curve is regular, you can determine by graphical or numerical interpolation the stimulus value at which the subject would give the response "heavier" 25% of the time and the point at which he would give this response 75% of the time. Half the difference between these two points is the difference threshold for this subject. Do you think the difference threshold is the same at both standards? How is the slope of the curve related to the acuity of the subject? How would you locate the point of subjective equality?

Part B

The importance of control of extraneous variables becomes apparent when a standard weight of a different size from the comparison weights is used. Comparison weights of 140, 160, 180, and 200 grams are used. In one condition a standard weight of the same size as the comparison weights is used. In the other condition a standard weight larger than the comparison weights is used. The blindfold is not used. Neither experimenter nor subject need know the weight of the oversize standard until the data have been collected. The two conditions may be graphed together for comparison. A systematic bias related to the variable of size will be apparent in most cases.

REFERENCES

Galanter, E. Contemporary psychophysics. In *New directions in psychology.* New York: Holt, Rinehart & Winston, 1962.

Galanter, E. *Textbook of elementary psychology.* Holden Day, San Francisco, 1966.

Data Sheet

Experiment 7:

The Difference Threshold for Weight

Part A

Trial	Weight				
	75	80	85	90	95
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total					

Trial	Weight				
	105	110	115	120	125
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total					

Trial	Weight				
	175	180	185	190	195
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total					

Trial	Weight				
	205	210	215	220	225
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total					

Data Sheet

Experiment 7:

The Difference Threshold for Weight

Part B

Equal Size Condition

Trial	Weight				
	170	180	190	200	210
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total					

Unequal Size Condition

Trial	Weight				
	170	180	190	200	210
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total					

EXPERIMENT

8 PHYSICAL MAGNITUDE AND PERCEIVED MAGNITUDE

In general, as the physical magnitude of a stimulus increases, so does its perceived magnitude; e.g., a 50-gram weight seems heavier than a 10-gram weight. The exact form of this psychophysical relationship has been subject to considerable investigation. Fechner proposed that

$$P = k \log S \qquad (1)$$

where P is the perceived magnitude of the stimulus, S is the physical magnitude, and k is a constant. Equation 1 is the equation for a straight line with slope k. Suppose we presented the subject with several different weights (e.g., S = 75 grams, 85 grams, 95 grams, etc.) and measured the perceived magnitude P of each weight on some psychological scale. Equation 1 predicts that P would be a linear function of $\log S$. That is, if we plotted P as a function of $\log S$, the function should approximate a straight line.

More recently, S. S. Stevens has proposed that the relationship between perceived magnitude and physical magnitude is described more accurately by the equation

$$P = k\, S^n \qquad (2)$$

where n is a power that varies from one perceptual continuum to another, e.g., n has one numerical value for apparent weight, another value for loudness, another for brightness, and so forth. Unlike Equation 1, Equation 2 predicts that $\log P$ will be a linear function of $\log S$. That is, if we rewrite Equation 2 in logarithmic form, we have

$$\log P = \log k + n \log S \qquad (3)$$

This is the equation for a straight line with slope n. It predicts that if we plotted $\log P$ as a function of $\log S$, the function would approximate a straight line. The purpose of this experiment is to determine which of the two equations, Fechner's or Stevens', describes more accurately the relationship between the physical magnitude and the perceived magnitude of a weight.

APPARATUS

Eight weights will be used, weighing 75, 85, 95, 115, 125, 175, 190, and 215 grams.

PROCEDURE

The perceived magnitude of each weight will be measured by the magnitude estimation procedure. This procedure is explained by the following instructions, which the experimenter (*E*) reads to the subject (*S*) before the experiment. (Since most students are unfamiliar with magnitude estimation procedure, it is recommended that the instructor give them some preliminary practice using line segments of various lengths drawn on the blackboard.) Instructions: "You will be presented with a series of weights in irregular order. Your task is to tell how heavy they seem by assigning numbers to them. Call the first stimulus any number that seems to you appropriate. Then assign successive numbers in such a way that they reflect your subjective impressions. For example, if a weight seems 20 times as heavy, assign it a number 20 times as large as the first. If it seems one-fifth as heavy, assign a number one-fifth as large, and so forth. Use fractions, whole numbers, or decimals, but make each assignment proportional to the heaviness as you perceive it."

After reading the instruction, *E* presents the blindfolded *S* with the eight weights in a random order. The first weight in the randomly ordered series is the standard stimulus for that *S* throughout the experiment, and *S* assigns it any number he pleases. Its number will remain fixed throughout the experiment. The *S* hefts each weight for 5 seconds, with elbow on the table, and judges the magnitude of the stimulus. The standard stimulus is presented before each of the other weights is lifted and the subject is informed that it is the standard. This procedure is repeated until *S* has judged each weight four times.

Use the space on the next page to list the weights in the order in which your *S* will lift them. Use a random order. The first weight listed is the standard. Below each weight in column *P* record the number *S* assigns to it on each of the four trials.

ANALYSIS

Combined data from the entire class can be used to prepare two separate figures, one for each equation. Fechner's equation can be evaluated by plotting *P* (mean magnitude estimate) as a function of log *S* (log grams). Stevens' equation can be evaluated by transforming the individual magnitude estimates logarithmically and plotting log *P* (mean log magnitude estimate) as a function of log *S* (log grams).

Serial Order	1		2		3		4		5		6		7		8	
S																
log *S*																
Trial	*P*	log *P*	*P*	log *P*	*P*	log *P*	*P*	log *P*	*P*	log *P*	*P*	log *P*	*P*	log *P*	*P*	log *P*
1																
2																
3																
4																
Sum																

REFERENCE

Stevens, S. S. A metric for the social consensus. *Science,* 1966, **151**, 530-541.

EXPERIMENT

9 ADAPTATION LEVEL

Judgment of the intensity of a stimulus may depend not only upon the physical magnitude of the stimulus, but also the subject's prior experience with the attribute being judged. The same moderately heated room seems warmer to a subject (*S*) having adapted to the cold outdoors than it does to one having adapted to a hot bath. In the present experiment subjects (*S*s) will be adapted to two different levels of lifted weight. One group will lift a set of weights substantially heavier than that lifted by the other group. After the two adaptation levels have been established, the two groups will be tested with a common set of weights, judging each weight along a nine-point scale of heaviness. During the test phase, the subject's (*S*'s) judgment of the heaviness of a given weight should depend upon the adaptation level established during the first phase of the experiment.

APPARATUS

Two sets of five weights each are used. The weights in Set L weigh 75, 85, 95, 105, and 115 grams; those in Set H weigh 175, 185, 195, 205, and 215 grams.

PROCEDURE

Group HH is adapted to Set H and Group LH is adapted to Set L. Immediately following the adaptation phase both groups are tested with Set H. One member of each pair of lab partners is assigned at random to Group HH, the other to Group LH, and it is decided at random which partner serves as first experimenter (*E*), which as second *E*. The latter step serves the important purpose of randomizing order of experiment treatment within pairs.

During the adaptation phase the blindfolded *S* receives 10 trials. On each trial he lifts all five weights in succession. Keeping his forearm on the table, he lifts the weight once, with a motion of hand and wrist, then puts it down. After lifting the weight he gives a judgment by naming one of the following categories, which he has memorized beforehand: Very Very Heavy (VVH), Very Heavy, Heavy, Medium Heavy, Medium, Medium Light, Light, Very Light, or Very Very Light. Before the experiment begins, *E* should ask *S* to repeat these nine categories in the order given above, to make sure that he knows them. The *E* records *S*'s judgment of each weight as VVH, VH, H, etc., in the "Category" column on page 55. The *E* should proceed smoothly from one trial to the next, with no indication to *S* that a trial has been completed.

After the 10 adaptation trials *S* receives 10 testing trials, lifting and judging the five appropriate weights on each trial. The *E* continues recording the judgments and should proceed smoothly from the adaptation trials to the testing trials without any interruption or warning to *S*. When the 10 test trials have been completed, *E* and *S* reverse roles and the procedure is repeated using the appropriate set(s) of weights.

CONTROLS

If the weights were presented in the same order on each trial, *S* might adopt some habitual sequence of judgments, impairing the accuracy of his judgments. The order in which the weights are presented should be varied at random from trial to trial. Each *E* should make up 20 separate orders of presentation, one for each trial, using a table of random numbers. The weights are to be listed on page 55, in the "Order" column, in their order of presentation.

RESULTS

Convert the category judgments recorded in the "Category" column into numerical scale values using the conversion table on this page. Record the numerical scale values in the "Scale Value" column. Calculate the mean of the five scale values for each of the 20 trials and record them in the last column. The two groups' judgments can be compared by calculating mean scale values of each group for each trial of the experiment.

Category	Scale Value	Category	Scale Value	Category	Scale Value
VVH	9	MH	6	L	3
VH	8	M	5	VL	2
H	7	ML	4	VVL	1

REFERENCE

Di Lollo, V. Contrast effects in the judgment of lifted weights. *Journal of Experimental Psychology*, 1964, 68, 383-387.

Data Sheet

Experiment 9:

Adaptation Level

Trial	Order	Category	Scale Value	Mean
1				
2				
3				
4				
5				

Trial	Order	Category	Scale Value	Mean
1				
2				
3				
4				
5				

(Continued)

Data Sheet (*Continued*)

Trial	Order	Category	Scale Value	Mean
6				
7				
8				
9				
10				

Trial	Order	Category	Scale Value	Mean
6				
7				
8				
9				
10				

EXPERIMENT

10 RELATIVE-SIZE ILLUSION

PROBLEM

It is well known that the size of an object is judged, in part, by comparison with other objects nearby in the field. A general theory of how objects are judged is called "Adaptation-Level" theory. The idea is that the perceiver establishes an "Adaptation Level" (AL) and then perceives all quantities by comparison with that AL. Of course, there are different ALs, for size, brightness, color, etc. We shall be concerned in these experiments with AL for distance.

In the neighborhood of large objects, the AL for distance should be large, and in the neighborhood of small objects, AL should be relatively low. The result can be an optical illusion.

MATERIALS

Each stimulus consists of a short line with a square at each end. The length of the line is varied, using the following five lengths:

(1) 20/32 inch
(2) 25/32 inch
(3) 30/32 inch
(4) 35/32 inch
(5) 40/32 inch

These lines are drawn, centered the long way, on sheets of paper; three copies of each are made, a total of 15 sheets of paper.

With each line length, squares of three sizes are used:

S (small), 5/16 inch
M (medium), 15/16 inch
L (large), 22/16 inch

The three papers with a 20/32-inch line have squares of 5/16 inch, 15/16 inch, and 22/16 inches drawn at the ends of the lines. The same is done for lines of length 25/32 inch, etc., finally producing 15 different sheets of stimulus papers.

In addition, a standard line (15/16 inch) with no square is provided.

PROCEDURE

Each experimenter is to bring a large book or notebook that can be erected as a stimulus-holder. The standard is placed on the holder and left there throughout the experiment.

The fifteen stimulus papers are shuffled by hand so as to be thoroughly disarranged.

The subject is shown each of the cards in order. He is to make a magnitude estimate of the apparent length of the *line*. The standard is called 100.

The subject's judgment is recorded in the appropriate place on the data sheet, the first column, under Trial 1.

The stimulus papers are again shuffled and disarranged. Then the procedure is repeated for Trial 2, and so forth up to Trial 6.

INSTRUCTIONS TO SUBJECT

"In this experiment you are to judge the length of a line. At the ends of the line are squares of various sizes, but you are to judge, not the size of the squares, but only the length of the line between them.

"Your responses are to be any numbers reflecting your judgment of the length of the line. Do not attempt consciously to correct for any illusory effect, but judge each line as it looks to you.

"You have a standard, having no squares in it, in view at all times. That standard has a value of 100 on the judgment, or magnitude-estimation scale. If the line between boxes seems longer than the standard, you might judge it 110, 140, 163, or anything you like. (Please use whole numbers.) If the line between boxes seems shorter than the standard, judge it less than 100, perhaps 80, or 40, or whatever seems correct to your eye.

"You will receive six trials through the set of stimuli. Judge each stimulus as you see it, not trying to be consistent or to overcome illusions, etc."

RESULTS

Total and average the response to the various lines, counting only Trials 3, 4, 5, and 6. Leave the first two trials aside as practice.

Plot the average judgment of the five lines with small boxes on a graph, mean judgment as a function of length of line.

On the same paper, plot the average judgments of the same five lines with medium boxes, as a separate line, and then the average judgment of the five lines with large boxes. The three sets of data should look somewhat like Fig. 2.

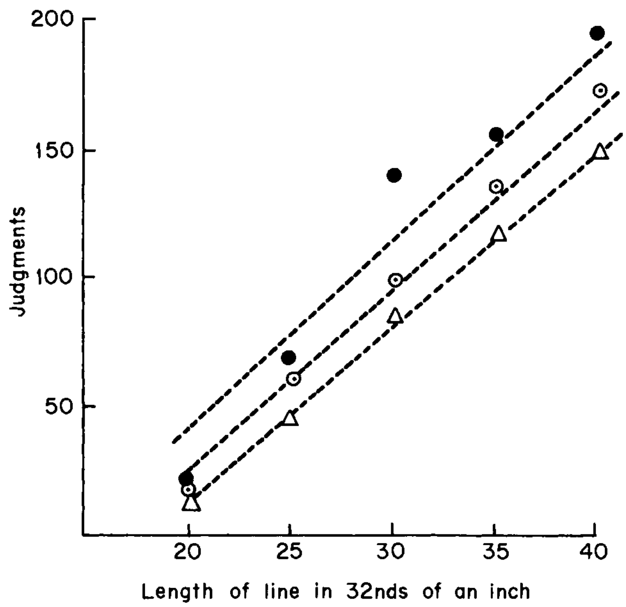


Fig 2 Mean judgment for various line lengths at three levels of box size.

Draw straight lines through the three sets of points. (You may find the data points curving downward slightly. This is caused by self-adaptation, for the line itself affects the AL. We disregard this relatively small effect in our calculations.)

DISCUSSION

(a) The slopes of the lines in this figure tell how judgments J vary with length of the line, L. The spaces between the lines are the result of size differences among the boxes. The greater the spaces, the greater the illusion.

The illusion can be measured approximately in inches. Suppose, for example, that judgments of a line with a small square are larger by 11 judgment units than judgments of the same line with a large square. The space between the lines is 11. To get this illusion into inches, we look at the slopes of the graph lines and determine how many inches corresponds to 11 judgment units.

To get a percentage illusion, the usual form in which illusions are reported, divide the amount of illusion in inches by the average length of lines being judged.

The slopes of the lines relating judgment to length of line are approximately ______________ .

The space between the line corresponding to small and the line for large squares is ______________ judgment units.

This corresponds to ______________ inches.

Since the average length of line is 15/16 inch, the Percentage Illusion is

______________.

(b) Above we calculated percentage illusion for the largest and smallest box. We also have a medium-sized box, and the illusion between the smallest and the medium box can be calculated, as well as between the medium box and the largest one.

If we compare very large and very small boxes, the illusion will be relatively great. With boxes that differ only slightly in size, the effect will be very small. Therefore, the magnitude of the illusion (the difference in line lengths caused by different boxes) depends upon how great the difference between boxes is.

One formation of this effect is that

$$\text{Proportion Illusion} = (B_2/B_1)^p - 1$$

Where B_2 and B_1 are the two boxes (B_2 being the larger box) and p is a constant, usually a rather small number around 0.10 or 0.15.

The Proportion Illusion for boxes S and M is ______________ .

The Proportion Illusion for boxes M and L is ______________ .

To compute an estimate of p, we use logarithms. Start with the above equation, and add 1 to both sides:

$$\text{Proportion Illusion} + 1 = (B_2/B_1)^p$$

Take logarithms of both sides, and

$$\log(\text{Proportional Illusion} + 1) = p \log(B_2/B_1)$$

Solving the equation for p, we have

$$p = \frac{\log(\text{Proportional Illusion} + 1)}{\log(B_2/B_1)}$$

Complete these calculations for all three possible ratios B_2/B_1; that is, L/S, L/M, and M/S.

Estimates of p for
L/S is ________________.
L/M is ________________.
M/S is ________________.

These three values should be fairly close together, for they are all estimates of the same (theoretical) quantity.

(c) Study your data and see whether the results are in the right direction to correspond to the AL theory. That is, is it correct to say that a given line appears (is judged) smaller when it is near large squares, than when it is near small squares? Furthermore, is *that* the result expected from the AL theory? Be sure before you answer. More exact theory goes as follows:

$$\text{AL} = L^a B^b K^{1-a-b}$$

This says that the adaptation level, in a given field, depends upon the length of the line L, the size of the box B, and a constant factor K depending upon the size of the paper, size of the desk, and other constant values in the field. Since people actually judge quite accurately, we expect that K is an important factor. The numbers a, b, and $1-a-b$ reflect the relative importance of the three factors in the field.

In the basic theory of adaptation level, Helson (see reference) says that AL is the weighted geometric mean of the factors in the field.

Now, the judgment depends upon L relative to AL, that is,

$$J = k\,L/\text{AL} \quad J = k\,(L^{1-a} B^{-b} K^{a+b-1})$$

Taking logarithms,

$$\log J = \log k + (1-a) \log L + (-b) \log B + (a+b-1) \log K$$

All the constant terms can be put together into one constant, giving

$$\log J = (1-a) \log L - b \log B + C$$

The mathematically inclined members of the class may now figure out how to calculate a and b from the data, so as to determine the weights of self-adaptation and of the box on the apparent lengths of line.

REFERENCE

Helson, H. *Adaptation level theory.* New York: Harper & Row, 1964.

Data Sheet

Experiment 10:

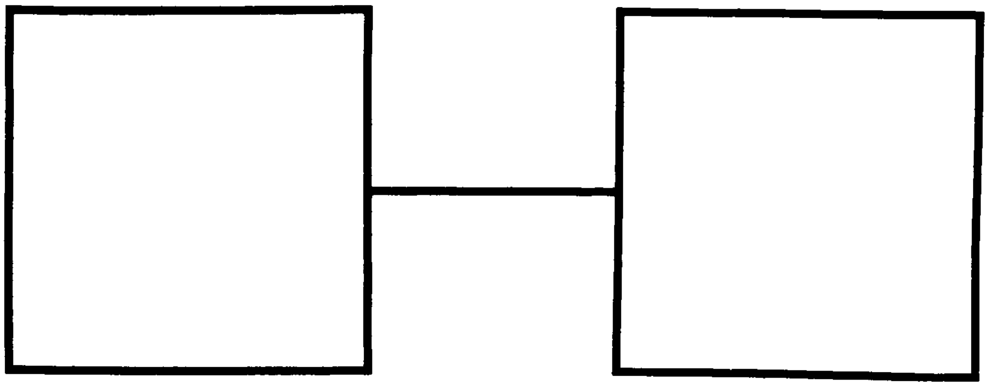
Judgment of Visual Illusion

Experimenter ______________

Subject ______________

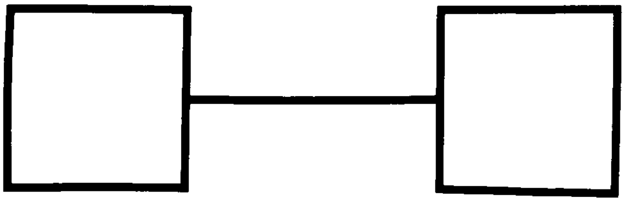
Subject First ________ Second ________

Trial:		1	2	3	4	5	6			
Box	Line	Resp						Box	Line	Total
S	1	___	___	___	___	___	___	S	1	___
S	2	___	___	___	___	___	___	S	2	___
S	3	___	___	___	___	___	___	S	3	___
S	4	___	___	___	___	___	___	S	4	___
S	5	___	___	___	___	___	___	S	5	___
M	1	___	___	___	___	___	___	M	1	___
M	2	___	___	___	___	___	___	M	2	___
M	3	___	___	___	___	___	___	M	3	___
M	4	___	___	___	___	___	___	M	4	___
M	5	___	___	___	___	___	___	M	5	___
L	1	___	___	___	___	___	___	L	1	___
L	2	___	___	___	___	___	___	L	2	___
L	3	___	___	___	___	___	___	L	3	___
L	4	___	___	___	___	___	___	L	4	___
L	5	___	___	___	___	___	___	L	5	___



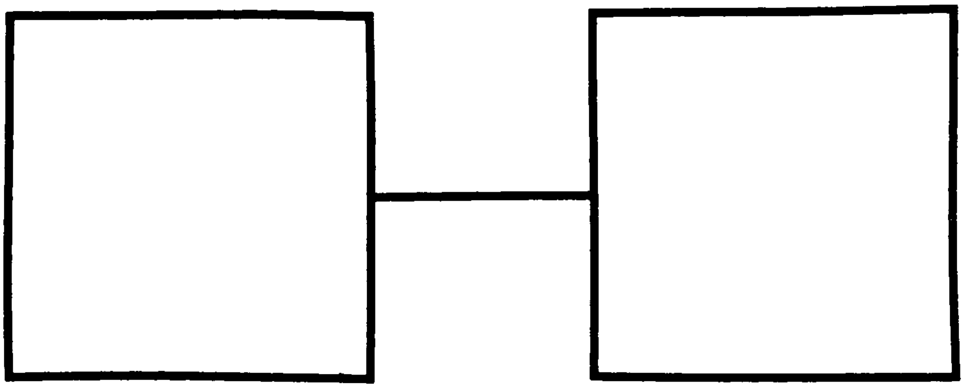
STANDARD

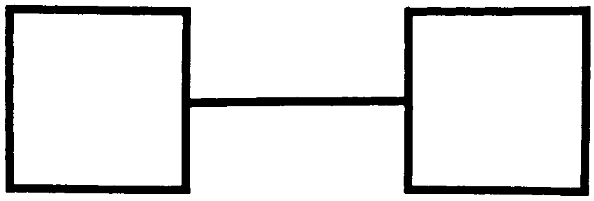
L 5



S 5

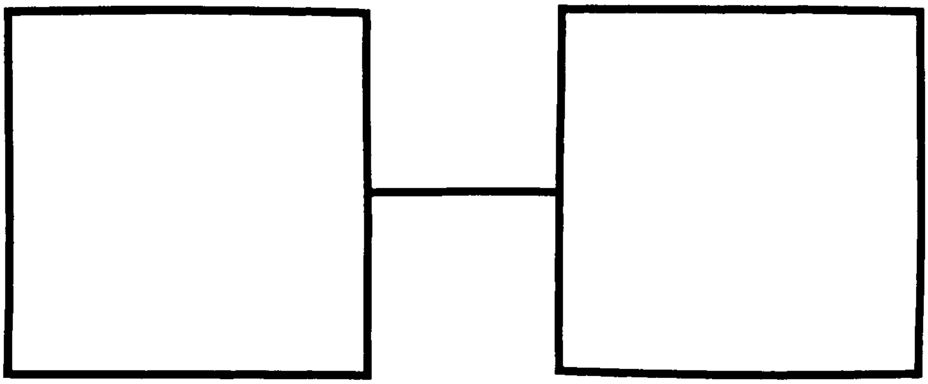
M 5





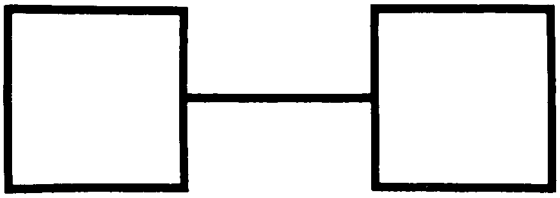
L 4

M 4



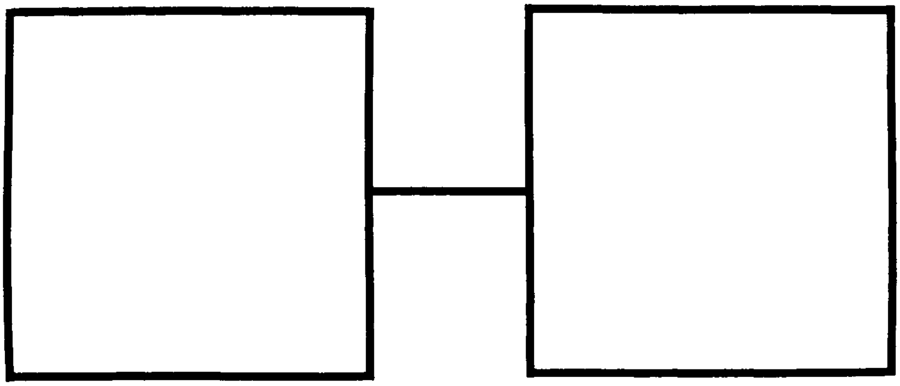
S 4

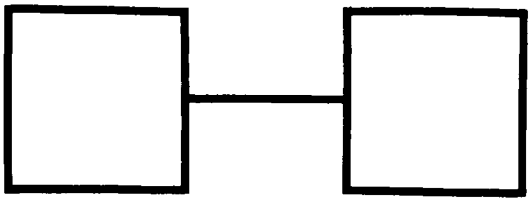
L 3



M 3

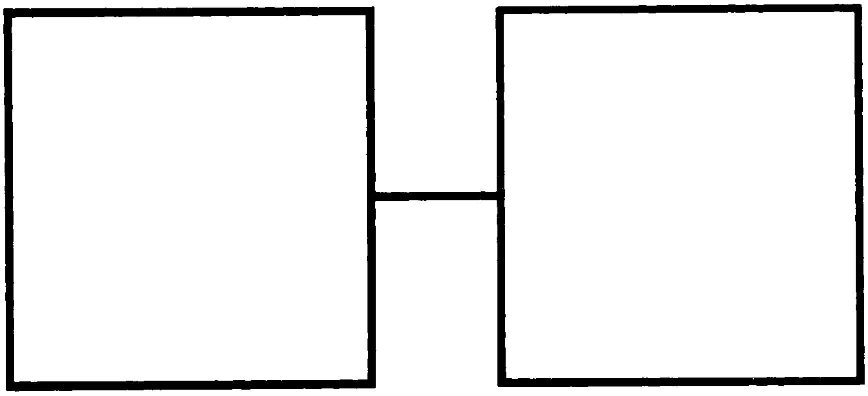
S 3





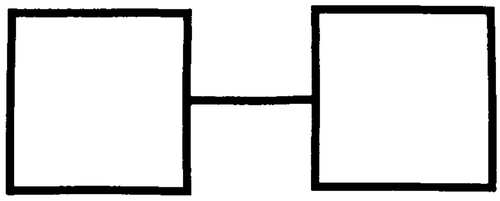
L 2

M 2



S 2

L 1



M 1

S 1

EXPERIMENT

11 VISUAL ACUITY IN THE RETINAL PERIPHERY

PROBLEM

Visual acuity can be measured in any of three different ways.

1. Minimum visible acuity–the measure of the smallest object that can be seen.
2. Minimum separable acuity–the measure of the least separation between two objects which can just be seen as separate.
3. Vernier acuity–the measure of the offset of two lines when the lines are just seen as discontinuous.

One of the problems in measuring acuity is the fact that objects appear to be of different sizes depending on their distance from the observer. An object appears large when near the observer and small when more distant. If we consider the angle made by the end points of the object and the observer's eye, this angle also varies as a function of distance, the angle being large when the object is close to the observer and small when the object is more distant. This angle is called the visual angle and is measured in degrees, minutes, and seconds of arc. The visual angle is very useful in acuity measures because it tells us directly what the size of the image is on the observer's retina, and we need not specify the size and distance of the object from the observer. Visual acuity in fact, is defined as the reciprocal of the visual angle expressed in minutes of arc (1/visual angle). If the least visual angle which can be seen is very small, then the ratio of 1/visual angle will be large and hence acuity will be high. On the other hand, if the least visual angle is large, then the ratio 1/visual angle will be small and acuity low. If we let e represent the width of an object, and R the distance of the object from the observer, then we can obtain the approximate visual angle in degrees by the formula

$$\text{Visual angle in degrees} \approx \frac{57.3e}{R}$$

where e and R are in the same units.

The two most important variables that determine visual acuity are level of illumination and retinal position. In the present experiment the level of illumination will be kept constant and minimum separable acuity determined as a function of retinal position.

APPARATUS

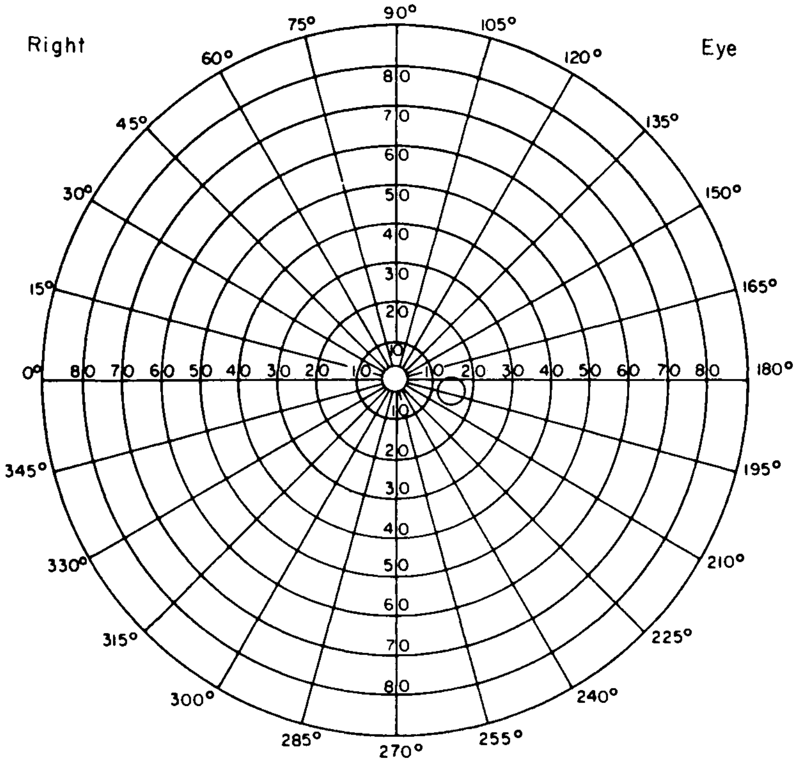
A perimeter and a set of Landolt Rings. Rubber cement aids in attaching stimuli to perimeter.

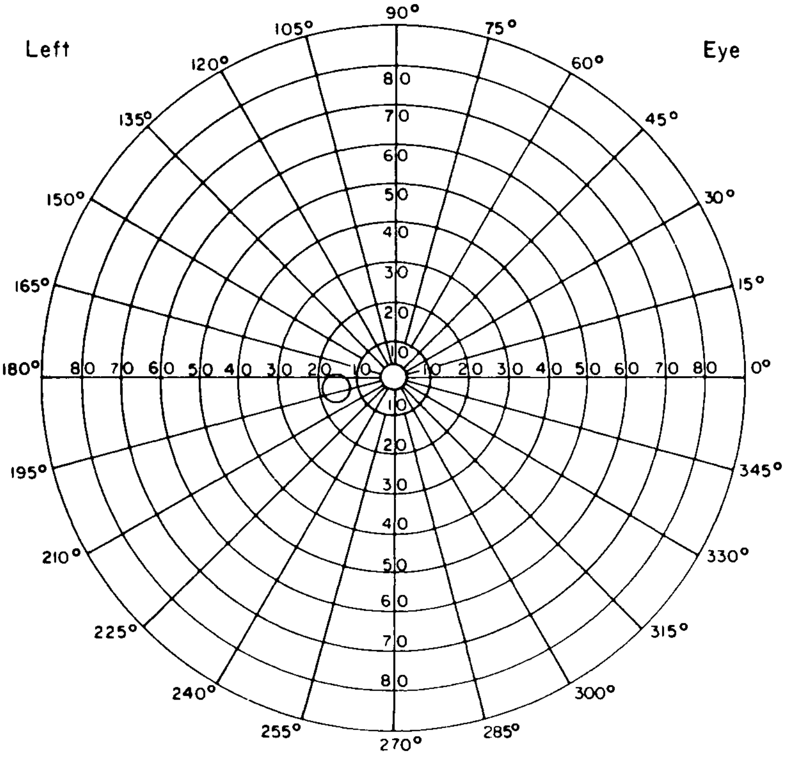
PROCEDURE

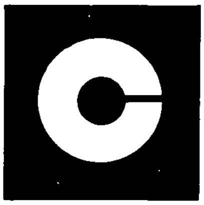
With the subject fixating the center of the perimeter with one eye, set the two arms of the perimeter in the horizontal position. Present the Landolt Rings in random order starting at the extreme periphery and moving slowly toward the fixation point until the subject reports seeing the gap in the ring. Record this location marked in degrees on the perimeter and select another stimulus ring. For each stimulus there are four positions of the gap in the ring, top, bottom, right, and left. Be sure to randomize the position of the gap from trial to trial, and have the subject identify the location of the gap when he sees it. Inform the subject of incorrect reports and repeat the trial for that stimulus later in the series. Present each stimulus five times. After having determined the acuity position for each stimulus on both right and left arms of the perimeter, rotate the arms to the vertical position and repeat the procedure. If time allows, your instructor may have you make determinations at other, intermediate, meridians. In addition, the subject's blind spot may be located.

RESULTS

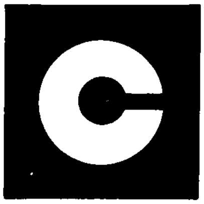
Plot the mean location of correct identifications for each stimulus on each meridian. Connect the points for the same stimuli with a circular line, thus giving an acuity map for the visual field. Also plot the location of the blind spot.


Right
Eye
90°
75°
105°
60°
120°
45°
135°
30°
150°
15°
165°
0°
180°
345°
195°
330°
210°
315°
225°
300°
240°
285°
255°
270°
80 70 60 50 40 30 20 10


Left
Eye
90°
105°
75°
120°
60°
135°
45°
150°
30°
165°
15°
180°
0°
195°
345°
210°
330°
225°
315°
240°
300°
255°
285°
270°
80 70 60 50 40 30 20 10

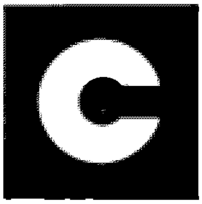


1 mm

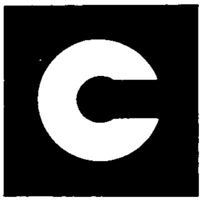


2 mm

3 mm



4 mm



5 mm

EXPERIMENT

12 TRANSFER OF TRAINING

PROBLEM

Transfer of training refers to the influence of experiences with a previous Task A upon performance of a current, different, Task B. Positive transfer is evidenced in a facilitatory influence of A upon B. For example, the learning of calculus (Task B) would most certainly be facilitated if one had previously learned algebra (Task A) as compared with if one had not. Negative transfer is evidenced by a disrupting influence of A upon B. For example, if the convention in traffic signals were suddenly reversed, it would be more difficult to learn to go on red and stop on green lights (Task B), having learned to stop on red and go on green (Task A).

To define a transfer effect of either kind, the following minimum design might be employed:

	Phase 1	Phase 2
Group 1	Perform Task A	Evaluate performance on Task B
Group 2	Rest (Task X)	Evaluate performance on Task B

The difference between Groups 1 and 2 in performance on Task B may then be attributed to the difference between Task A and Rest. A superiority of Group 1 over Group 2 would indicate positive transfer, and the reverse would indicate negative transfer.

The following experiment employs such a design to study bilateral transfer in a mirror drawing task. It is hypothesized that training with one hand relative to no such training will improve later performance using the other hand.

APPARATUS

Materials are mirror-drawing boards, star-tracing sheets, pencils, and a timepiece with a sweep-second hand.

PROCEDURE

Students work in pairs, one acting as experimenter and the other as subject. Half of the subjects are randomly assigned to each of the two experimental groups, care being taken to equalize the number of males and the number of females in each group.

Subjects assigned to Group 1 receive ten trials on which they trace the star using the nonpreferred hand, followed immediately by ten trials with the perferred hand. Subjects in Group 2 receive ten trials with the preferred hand, but no pretraining with the nonpreferred hand.

The experimenter should number all star sheets and arrange them in order at the beginning of the series, so that the trials once begun may be run off in the most efficient and orderly manner. When a star sheet is placed in position, the point with the line through it should be toward the mirror. The subject sits at a table with his hand in writing position. The mirror board is placed so that the subject may see his writing hand in the mirror, but direct vision of that hand and the star being traced is blocked.

The experimenter should see that the subject follows these instructions precisely:

"Trace counterclockwise with the right hand and clockwise with the left hand. At the beginning of a trial place the point of your pencil between the boundary lines of the star at the midline of the star point nearest the mirror. At a signal from the experimenter, you will begin tracing as rapidly as possible around the star. DO NOT, HOWEVER, GO OVER ANY BOUNDARY LINES. If the pencil should cross a boundary, you must re-enter at the point of departure before going on. Between trials of a series, keep your tracing hand concealed behind the screen. You should never see the tracing hand in direct vision during or between trials, and should do nothing with it besides tracing."

In the 15 seconds between trials the experimenter changes to a new star sheet, records on the data sheet the time (in seconds) required for completion of the last circuit around the star and gives the subject the signal to start the next trial. No practice trials are allowed.

Upon completion of all the trials for the first subject in the pair, the members of the pair reverse roles, and precisely the same procedures are followed for the second subject.

RESULTS

The experimenter should make a record of the time required to complete each trial and the number of errors observed. An error may be defined as any excursion of the pencil outside the boundaries of the star.

Performance changes in terms of seconds to complete a trial may be plotted as a function of trials. Group 1 and 2 should be compared with respect to level of performance in using the preferred hand.

It may be instructive to analyze separately the data for the first and second subjects in the pair. The second subject differs from the first in that, while he was the experimenter, he had the opportunity to observe the first subject complete his trials. One might anticipate that such observation might provide the basis for positive transfer. The extent of such transfer effects may be estimated by comparing the first with the second subjects within each of the two groups.

Data Sheet

Experiment 12:

Bilateral Transfer in Mirror Drawing

Trial		Time	Errors
Nonpref.	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		
Pref.	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		

SHORT-TERM MEMORY: INTRODUCTION

When the human brain processes information, it often stores some information temporarily before disposing of it finally. One familiar form of short-term memory is rehearsal—if asked to remember the name HORACE OLIVEBUN, you may repeat it to yourself several times. During rehearsal the information is held, though some distortion may arise from the very process of rehearsal.

Even when they do not rehearse, people can retain information for a time, by a process called "short-term memory." In short-term memory the information is not permanently fixed and cannot be remembered after a long time. Nor need the material be rehearsed constantly. Short-term memory is convenient to study in the laboratory because it occurs within a few seconds or minutes, and so can be observed within a single laboratory session, but is not so fleeting that we need special equipment to observe it.

People often have occasion to remember numbers for a few moments, then reproduce them. For example, telephone numbers are looked up in a book and then dialed, serial numbers are transferred from automobile to license application, and amounts of money are copied. It is a common experience that any interruption increases the likelihood of error or complete failure to remember the number. In these experiments we shall investigate the process of short-term memory for digits. The three experiments explore three different aspects of the process, studying the length of the number, the structure of the number, and the duration and structure of the intervening activity. The general purpose of experiments of this type is to study how information is stored in short-term memory, what happens to it during storage (decay, interference, rearrangement, dislocation), and how it is retrieved at the time of test.

First, we study the forgetting of numbers of different lengths. One hypothesis is that each digit in a number is subject to random decay in memory, and the more digits, the higher the probability that at least one digit has decayed. This hypothesis will be tested, and the results put us in a position to consider more detailed ideas.

Second, we study the structure of the number. Here the idea is that information is restructured or recoded before it goes into memory, and that the ability to remember something depends upon the code into which it is translated. The results of this experiment may show that short-term memory is an active process of incorporation, not a mere matter of "copying down" the information.

Third, we inquire about the process of forgetting. It is apparent that if we let the subject rehearse a number for 10 seconds he will still be able to remember and recall it. He can remember indefinitely if he will keep rehearsing. Therefore, all short-term memory experiments use some activity between exposure and recall, merely to prevent rehearsal. However it is possible that the activity also brings about forgetting, by some form of interference. Our third experiment is designed to tell us more about the conditions under which this interference is strongest.

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EXPERIMENT

13 SHORT-TERM MEMORY FOR DIGITS: I

PROBLEM

It is a common experience that numbers are difficult to remember. You look up a telephone number, and as you go to the telephone someone says, "What month is it?" You say, "November," and then cannot remember the telephone number. Apparently the number is "stored" somehow for a short period, from book to telephone and that storage can easily be disrupted.

It has been shown (Peterson & Peterson, 1959) that short-term memory decays rapidly. However, the subject must be occupied in some other task, so as to prevent rehearsal. In these experiments, as an interfering task we require the subject to give three examples of a common category, e.g., three fruits, or three cities.

Clearly, very long numbers are difficult to remember correctly, and shorter numbers are easier. In our first experiment we study how memory depends upon the lenth of the number to be remembered.

PROCEDURE

Instructions. The experimenter (*E*) will read a number, then a category name, either fruits, colors, cities, or animals. The subject first must give three examples of the category, then try to repeat the number. His answer is scored as correct (it must be completely correct) or wrong. The digits are read evenly, one each second, then the category name is given in rhythm. The subject must give examples of the category immediately, with no pause to rehearse the number.

Two individual data sheets are given in the manual. One student is experimenter first and uses Data Sheet A. The other student paired with him is subject first and uses Data Sheet B.

RESULTS

After all pairs of subjects are finished, each person counts tl rect of 1-digit, 2-digit, 3-digit numbers, etc. This gives hi 1-digit to 7-digit, and since there are four trials at each, the low as 0 or as high as 4.

Put these totals on the blackboard, and when all are up, e copy the data for his own report.

Ordinarily, 1-digit numbers will be remembered almost 7-digit numbers will be quite difficult. Draw a graph showing of correct answers, for the group, as a function of the num the number.

CONCLUSIONS

From this graph we can see how the difficulty of a number its length. What does this signify for tasks like using telep using social security, student, draft board, and other numb life? What would happen if the telephone company had to ad to your telephone number?

THEORY

A simple theory is that longer numbers are not so well remer there is more to remember, and forgetting of any part is scor failure of the item.

Suppose that a single digit is remembered with a certain Imagine that when there are two digits each is remembered w R, and forgetting one digit is independent of forgetting the otl probability of remembering both digits is R^2. If the numl symbolized by N, then the probability of remembering all

A simple method of testing this theory is to take the obser of 7-digit numbers remembered and call this P_7. Then

$$P_7 = R^7.$$

Knowing P_7 we can find R by taking the seventh root of P_7 timate of R, written R, we can calculate predictions for th $P_1, P_2, \cdots, P_7$.

Make these computations and see whether the resulting pr close to the data points. (In our experience, in previous clas be.)

If your data are like ours, they will be far from the values predicted by this simple theory. The result will no doubt show that small numbers are too easy as compared with long numbers. This, in turn, means that some additional sources of difficulty must appear with long numbers. What might these be?

Figure 3 shows the results of the experiment above as collected by one class of freshmen at Indiana University. Notice that these subjects got about .22 correct when numbers had seven digits. This value was used to fit the one-component theory, by writing

R^N = proportion correct

$R^7 = .22$

$R = .22^{(1/7)} = .22^{.143}$

$R = .805$

The "Predicted" curve is R^N where N is the number of digits in the number. Its values are R, R^2, R^3, and so forth, that is, .805, $.805^2 = .648$, $.805^3 = .522$, and so forth.

Notice that the theoretical curve is clearly *not* close to the observed data.

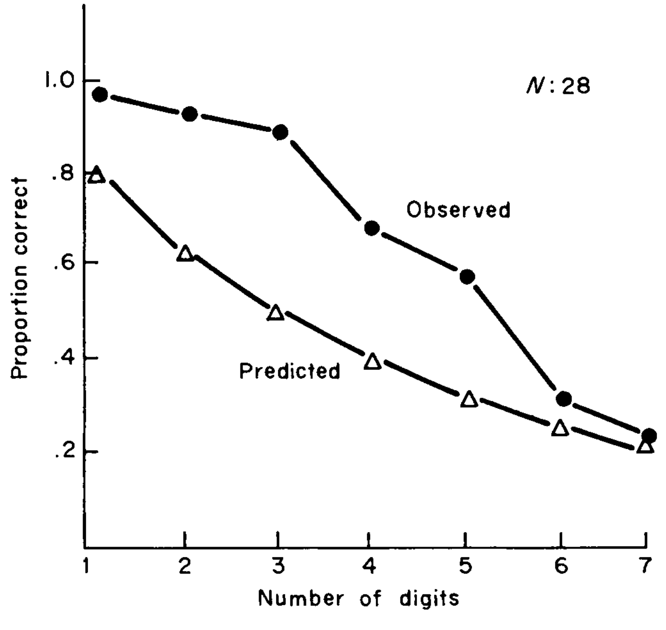

Fig 3 Predicted and observed proportion of correct responses as a function of number of digits in number.

Data Sheet

Experiment 13: **Name** ______________________

Subject First ______________________

Short-Term Memory for Digits: I **Experimenter First** ______________________

Part A

Answer	Stimulus	Interfering task	Answer	Stimulus	Interfering task
______	1335	FRUIT	______	7278	CITIES
______	326579	COLORS	______	2563456	COLORS
______	54	CITIES	______	4	ANIMALS
______	83987	ANIMALS	______	643	FRUIT
______	445	COLORS	______	644523	ANIMALS
______	3	FRUIT	______	326	CITIES
______	7835882	ANIMALS	______	93	COLORS
______	965342	CITIES	______	3454572	FRUIT
______	24	ANIMALS	______	5	COLORS
______	272789	FRUIT	______	56391	FRUIT
______	9758	COLORS	______	12511	CITIES
______	7	CITIES	______	4678	ANIMALS
______	125	ANIMALS			
______	76	FRUIT			
______	4553245	CITIES			
______	34521	COLORS			

Data Sheet

Experiment 13: Name ____________________

Subject First ____________________

Short-Term Memory for Digits: I Experimenter First ____________________

Part B

Answer	Stimulus	Interfering task	Answer	Stimulus	Interfering task
______	4678	ANIMALS	______	7	CITIES
______	12511	CITIES	______	9758	COLORS
______	56391	FRUIT	______	272789	FRUIT
______	5	COLORS	______	24	ANIMALS
______	3454572	FRUIT	______	965342	CITIES
______	93	COLORS	______	7835882	ANIMALS
______	326	CITIES	______	3	FRUIT
______	644523	ANIMALS	______	445	COLORS
______	643	FRUIT	______	83987	ANIMALS
______	4	ANIMALS	______	54	CITIES
______	2563456	COLORS	______	326579	COLORS
______	7278	CITIES	______	1335	FRUIT
______	34521	COLORS			
______	4553245	CITIES			
______	76	FRUIT			
______	125	ANIMALS			

EXPERIMENT

14 SHORT-TERM MEMORY FOR DIGITS: II

PROBLEM

Some numbers are more difficult to remember than others even though they contain the same number of digits. Easy numbers can be organized into a pattern which is easily remembered and generated, whereas difficult numbers are more difficult to organize.

For this experiment we have made up a list of 6-digit numbers that vary in difficulty.

Your procedure is much as in Digit Experiment I. Again, the experimenter on each trial presents a number, then a category, and the subject must at once give three samples of the category, then repeat the number.

Lists of numbers and the categories called for are given separately. Read the digits of a list one per second, then give the category. Be sure to require rapid verbal answers so that the subject cannot rehearse or reorganize the digits before the interfering task begins.

We go through six sets of numbers.

RESULTS

The easy numbers were constructed using a few simple rules. First, large segments were consecutive numbers like 5-6-7-8. A second alternative was counting by twos, such as 8-6-4-2. Third, a single digit might be repeated, as 4-4-4-4. Fourth, a simple alternation as 4-3-4-3. These patterns were introduced as organizing principles within the number.

Now, an easy number should be one that follows one of the above principles through from beginning to end. For example, 6-5-4-3-2-1.

A more difficult number would divide into two parts, each part following an organizational principle. For example, 1-2-3 5-6-5. A more difficult item might divide into three parts, as 5-4 1-2 7-7. A very difficult item presumably does not organize at all, such as 5 2 1 7 1 9.

In your experiment, the main datum is the proportion of subjects correctly remembering an item. You will find the items classified by a number in parentheses. Items of Type 1 form one unit using one of the above rules of succession, alternation, double succession, or repetition. Type 2 forms into two units, etc.

Notice that on your data sheets the six different interfering tasks, ANIMALS, BIRDS, FRUITS, COLORS, CITIES, and INSECTS are so arranged that ANIMALS goes once with an item of each type; 1, 2, etc. BIRDS likewise goes with each type once, etc. Therefore, the difficulty of the *number* is not confounded with the difficulty of the interfering *task*. Thus, we have taken into account the possibility that it may be easier to name three colors than, say, three insects.

To see whether it is easier to recall after one interpolated task than another, count the number of crorect responses given by the subject to each of the categories. There are six items for each, so the total is a number 0-6.

DISCUSSION

Plot the proportion of correct recalls as a function of the structure of the lists, 1-6. Remember that Type 1 organize into a single structure, 2 into two parts, 3 into three parts, etc. Therefore, your plot is *proportion remembered* as a function of *number of functional parts* to the number.

Compare your results with those of Digit Experiment I. Notice that the numbers used in Experiment I were very disorganized, like Type 6 of this experiment. Are the results of the two experiments comparable?

Consider practical applications of the finding that some digits are easier to remember than others. Also, consider the theoretical implications of how strings of digits are stored and remembered.

Experiment 14: Raw Data Sheet

Short-Term Memory for Digits: II

Answer	Stimulus	Interfering task	Type	Answer	Stimulus	Interfering task	Type
______	772345	ANIMALS	(2)	______	432933	ANIMALS	(3)
______	222222	BIRDS	(1)	______	582259	FRUITS	(5)
______	522671	FRUITS	(4)	______	345678	CITIES	(1)
______	255234	COLORS	(3)	______	234511	COLORS	(2)
______	368137	CITIES	(6)	______	845367	INSECTS	(4)
______	613375	INSECTS	(5)	______	614852	BIRDS	(6)
______	765432	FRUITS	(1)	______	792571	FRUITS	(6)
______	298753	COLORS	(4)	______	812777	BIRDS	(3)
______	678552	CITIES	(3)	______	149772	COLORS	(5)
______	952471	INSECTS	(6)	______	333333	INSECTS	(1)
______	829947	ANIMALS	(5)	______	894321	CITIES	(2)
______	234888	BIRDS	(2)	______	997625	ANIMALS	(4)
______	621349	CITIES	(4)	______	947226	CITIES	(5)
______	584927	ANIMALS	(6)	______	765477	INSECTS	(2)
______	654399	FRUITS	(3)	______	136842	COLORS	(6)
______	336182	BIRDS	(5)	______	411388	BIRDS	(4)
______	888888	COLORS	(1)	______	812777	FRUITS	(3)
______	981167	INSECTS	(3)	______	444444	ANIMALS	(1)

Data Sheet

Experiment 14:

Short-Term Memory for Digits: II

For Each Subject and Each Number Type,
Total Correct Responses

Subject Number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Class Total
Type 1																
Type 2																
Type 3																
Type 4																
Type 5																
Type 6																

If your class provided N subjects, then there were $6N$ total tries for each number Type. Therefore, if the Class Totals on the right are each divided by $6N$, the result is the proportion correct for each item type.

Proportion Correct by Item Type

Item Type	Proportion correct responses
1	
2	
3	
4	
5	
6	

(Continued)

Proportion Correct by Category

Category	Proportion correct responses
COLORS	
BIRDS	
FRUITS	
ANIMALS	
CITIES	
INSECTS	

EXPERIMENT

15 SHORT-TERM MEMORY FOR DIGITS: III

PROBLEM

To get rapid short-term forgetting for the two previous experiments we used an intervening task, such as naming three cities. You would expect that the amount of forgetting might depend upon the nature of this intervening task. It is well known that forgetting depends, not only on the thing learned, but also on what transpires during the forgetting interval.

It is generally agreed that activity during the forgetting interval can disrupt either the memory traces or the means of access to memories. In the present experiment, we attempt to determine more about this interference. Suppose that the subject, while trying to remember a number, is required to understand and say numbers. Certainly we might expect serious interference between these two tasks, on the basis of similar *content.* If the subject, while remembering a number, were understanding and saying words, there should be less interference because of dissimilar content. This prediction assumes that interference is between different items of content, and that interference comes about through similarity of content.

Another hypothesis is that forgetting comes about because the short-term memory is filled with new material, pushing out the number to be remembered. If this hypothesis is true, then interference should be great whenever the subject is forced to remember and recall a relatively large amount of material; on the other hand, the subject should remember relatively well when his task makes little demand upon his short-term memory *capacity.*

In the present experiment we shall test both of these hypotheses, the *content* hypothesis and the *capacity* hypothesis, within the same experiment. In every problem we study a subject trying to remember a 5-digit number, with different activities *interpolated* between learning and test of the number. One variable is whether the intervening task uses numbers or words (similar or dissimilar to the test content), the other variable is whether the interpolated task makes a light or heavy demand upon memory.

PROCEDURE

A number is read by *E* to *S*, as in Experiments I and II, but then the *E* gives different tasks to *S* depending upon the condition of the experiment.

Condition I (Similar Content, low memory load). The experimenter gives the subject five 2-digit numbers, and the subject is to give back the next larger number; for example, "32 - thirty-three." After the subject has responded to the fifth number, the Experimenter says "Test," at which time *S* is to give back the original number.

Condition II (Dissimilar Content, low memory load). The experimenter gives five common adjectives, and the subject is to give the opposite; for example, "Light–Dark." This is the interpolated task.

Condition III (Similar Content, high memory load). The experimenter gives the subject a second 5-digit number as interpolated task, and the subject is to give immediately the five digits in reverse order; Example, "53486–six-eight-four-three-five." Then the original number is to be recalled.

Condition IV (Dissimilar Content, high memory load). The experimenter gives the subject five adjectives one right after the other, and then the subject is to give the same list back in reversed order; for example, "red-tall-light-big-tender," and the subject responds "tender-big-light-tall-red." Then the original number is to be recalled.

A set of material for each condition is given in the manual. Each experimenter is to set up an order for giving the four conditions; and, within the class, each condition should be given first, second, third, and fourth equally often.

RESULTS

As in the previous experiments, score the proportion of numbers recalled correctly as a function of the type of interpolated material. An answer should be called correct only if all five digits are correct and in the right order. The totals for the class as a whole should be entered in the table below.

Proportion of Numbers Correctly Remembered

Type of interpolated task		
Content	Memory load	Proportion correct responses
Similar	Low	____________
Dissimilar	Low	____________
Similar	High	____________
Dissimilar	High	____________

DISCUSSION

The basic question about forgetting is the conditions that result in forgetting. Two general approaches contrasted here are (a) the idea that memories are disrupted or access to them is reduced when similar material is processed, versus (b) the idea that it is not the material, but a limited amount of storage space that is critical, so that one thing drops from short-term memory when another thing (even though dissimilar) is brought in. These hypotheses are not necessarily incompatible, for both influences might be found. Which hypothesis fits the data from your class?

Data Sheet

Experiment 15:

Short-Term Memory for Digits: III

Condition I

Response	Item	Intervening task
________	36276	59-29-93-56-69
________	53946	71-63-17-55-25
________	24761	79-10-47-88-93
________	61374	61-42-82-13-63
________	85317	15-11-40-71-26
________	42791	89-77-87-75-51
________	97153	31-42-94-24-81
________	15372	11-30-19-65-44
________	59354	28-64-95-23-14
________	63859	48-72-18-15-94

Condition II

Response	Item	Intervening task
________	48127	light up white go big
________	16739	in first left high odd
________	34931	front good shut wet push
________	27458	male rough slow day near
________	89263	low right last thin out
________	95527	light stop black down fast
________	69372	closed night late smooth female
________	34786	pull dry soft bad back
________	99247	even far open hard dark
________	74881	once fat little inside early

(Continued)

Data Sheet

Experiment 15: *(Continued)*

Condition III

Response	Item	Intervening task
________	86352	71739
________	25387	29523
________	17954	57058
________	46827	66031
________	79228	27035
________	73549	58329
________	59382	21597
________	23758	64181
________	58493	76254
________	66493	64573

Condition IV

Response	Item	Intervening task
________	91853	once fat little inside early
________	83735	even far open hard dark
________	38509	pull dry soft bad back
________	14173	closed night late smooth female
________	38598	light stop black down fast
________	47951	low right last thin out
________	63274	male rough slow day near
________	27469	front good shut wet push
________	18657	in first left high odd
________	35418	light up white go big

EXPERIMENT

16 SERIAL LEARNING

PROBLEM

In serial learning the subject must learn to give a set of responses in a particular order. Doing things in the right order is a crucial ability, manifested in speech and exemplified by the difference between "Furry fight furious wildcats battles," and "Furry wildcats fight furious battles."

CONTROLS

Suppose that a student is to memorize a list of nonsense syllables in the correct order. He must learn each syllable, and then must learn when to give it. If he does this by associating the syllable (as response) to the previous syllable (as stimulus), then all items should be approximately equally easy to learn, provided the syllables have the same intrinsic difficulty. In these experiments, the syllables are all drawn from the list below and are all of intermediate difficulty. Some syllables may be easier to learn than others for reasons having nothing to do with their positions in the list. We can control for this possibility by using a different serial order for each *S*. One way of doing this is for each *E* to make up a random serial order for his 12 syllables, using a table of random numbers. Copy the syllables in the space provided in the second column of the data sheet, in the serial order that will be used during the experiment.

It is usually found that the items just past the middle of the serial list are most difficult to learn. If the controls above have been executed well, this cannot be explained by differences in item difficulty.

MATERIALS

Since each student will serve alternately as *E* and *S*, two separate lists of 12 syllables each will be used, List A and List B, printed below. Each syllable has an association value of 47% as determined by Glaze (Hilgard, 1951).

List A		List B	
BEK	HIF	YAD	TAJ
PEF	LUD	RIW	REH
NOL	MUB	ZET	MOQ
CAX	VUS	VOG	DIJ
VOH	BIH	KUG	XIP
FAH	MEH	QOF	NUY

PROCEDURE

The *E* tells *S* to listen carefully to the list. When *E* spells a given syllable, *S* is to respond by spelling out the next syllable in the series, within 5 seconds. The *E* then recites the list aloud, spelling out the letters of each nonsense syllable. He should speak distinctly, at a rate of about one nonsense syllable per second. The *E* presents the entire list in this manner, recording *S*'s responses on data sheet. Following an intertrial interval of 1 minute, the list is presented again in the same serial order. This procedure is repeated until *S* has had 9 presentations of the list, beyond the first reading.

RESULTS

For serial positions 2 through 12, the experiment records in the third column the total number of trials on which *S* failed to give a correct anticipation. A failure is counted unless all three letters were given in the correct order. Data from the entire class can be combined, and the class should plot mean errors as a function of serial position. Of the incorrect answers given at each position, what proportion were syllables that would have been correct at some other position in the list? That is, what proportion were *forward* or *backward* association errors?

DISCUSSION

(a) Is the curve flat, indicating that all serial positions are equally difficult? For each subject, compare his errors in serial positions 7 and 8 with his errors in serial positions 2 and 12. (This is a comparison of "middle of the list" with "end of the list.") For each subject, if he makes more errors in positions 7 and 8 than in 2 and 12, give him a "+." If he makes more errors in positions 2 and 12 than in 7 and 8, give him a "–." If he makes the same total errors in 7 and 8 as in 2 and 12, give him a "0." Perform a simple binomial sign test on the data. What can you conclude about flatness?

(b) What is the shape of the serial-position curve for the class? Where is the maximum number of errors? See what explanations your class can suggest, from their experience as subjects.

REFERENCE

Hilgard, E. R. Methods and procedures in the study of learning. In S. S. Stevens (Ed.), *Handbook of experimental psychology*. New York: Wiley, 1951.

Data Sheet

Experiment 16:

Serial-Position Effect

Serial Position	Syllable	Total Errors	Trial								
			1	2	3	4	5	6	7	8	9
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

EXPERIMENT

17 SERIAL LEARNING AND UNUSUAL ITEMS

PROBLEM

The serial-position effect found in Experiment 16 is difficult to explain, although it is always found. One possibility is that the middle items in the list are difficult to *differentiate,* for some reason—that they run together in memory and cause confusion. If this is true, of course, we might expect the subjects to make many errors by giving the syllables in the wrong order. Is this what happened in Experiment 12?

Another possible explanation of the serial-position effect is that the subject must construct some "system" by which he interrelates all the items in the list, and the items at the beginning and end of the list are most easily integrated into this overall system. This idea is that the difficulty of the list depends upon *integration,* rather than *differentiation,* of items.

Now consider a list made up of 2-digit numbers, with a nonsense syllable in the difficult eighth position. The syllable is located where the serial-position effect should be at its worst, but it is highly distinctive and can easily be *differentiated* from the digits. On the other hand, not being a number at all, it should be relatively difficult to *integrate* with the list.

If we compare learning of this syllable with learning of a corresponding syllable in the usual, all-syllable list (as in Experiment 12) we can find out whether it is easier or harder. If it is easier, then the difficulty in the hard serial positions may be due to difficulties of differentiation. If the isolated syllable in a list of digits is harder to learn than the same syllable in a list of syllables, then the difficulty is probably caused by difficulties of integration. If it is equally difficult, then some other factor must be causing the difficulty.

MATERIALS

As in Experiment 16, each experimenter should make up a list in random order, except that the *unusual* item should always be placed in the eighth position. If this experiment is run jointly with Experiment 16, then one student of each pair should be in the control group (getting a nonsense-syllable list as in Experiment 16) and the other in the experimental group (a list of 2-digit numbers, drawn from the random number table, with one nonsense syllable in the eighth position). If the control subject learns List A, from Experiment 16, then the experimental subject's nonsense syllable should come from List B. The instructor should choose these odd syllables, taking one that is used as the eighth item for some control subject and giving it to an experimental subject of another pair.

PROCEDURE

Exactly as in Experiment 16.

RESULTS

Again, mean errors should be plotted as a function of serial position, the experimental and control conditions separately. Compare the performance at location 8 in the two groups.

What explanations can you provide?

Data Sheet

Experiment 17:

Serial-Position Effect

Serial Position	Syllable	Total Errors	Trial 1	2	3	4	5	6	7	8	9
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

TWO PERSON GAMES: INTRODUCTION

In social situations people exert power over one another. In elementary terms, power over another person is the ability to affect his responses.

In reinforcement theory, psychologists talk about modifying the behavior of an organism or "subject" by rewards and punishments. Although the term "subject" is intended to be neutral, it makes sense as a term in social psychology, for the subject in a learning experiment has very little control over the behavior of the experimenter, although the experimenter has control over the subject.

If we try to apply reinforcement theory to human affairs, we find that there is not an experimenter in the usual sense. Instead, the person who administers rewards and punishments is also subject to the rewards and punishments of others. In particular, there are many *reciprocal* power relationships. The small store-owner pays his sales clerks, and presumably can give raises or cuts in pay to reward or punish behavior. Actually, of course, the clerks can respond with more or less efficient and cheerful behavior, and in an emergency may strike, thereby rewarding or punishing the storekeeper. Rewards and punishments in the hands of one person may not be applied because of countervailing power in the hands of others.

EXPERIMENT

18 TWO-PERSON GAMES: I

Serious study of interactions began with Game Theory, the mathematical theory of competitive games like poker. Whether you win at poker depends upon how you play and also upon the plays made by others in the game.

In a game, each player chooses what is called his "strategy." The rules of the game determine the "payoff" to each player, given the strategies of the players. The mathematical problem is to determine the most effective strategy each player can choose, and the psychological question is what strategies subjects will actually choose.

In the experiments to follow, there are only two players and each has only two available responses. The rules of the game determine how many points each player gets, given the responses of the two subjects. Call the players A and B and theri responses "YES" and "NO."

A simplified model of two-person power relationships has been put forward by Thibaut and Kelley, and employs a part of game theory. In particular, Thibaut and Kelley discuss two-person, non-zero-sum games.*

The general procedure is that each of two players, at the same time and secretely, chooses a response. These two choices determine a payoff for each player, and the payoff is announced by the referee (experimenter). In these games the payoff is determined by the responses made by both subjects jointly.

*In a game like poker, every time one player wins, the other loses a corresponding amount, so that the total amount in the game is a constant. The sum of the payoffs to all players, in any play, is zero. In a non-zero-sum game all players may win, or all may lose, and the sum of the payoffs to all players need not be zero.

Such a game is illustrated below.

B chooses \ A chooses	YES	NO
YES	+6	+1
NO	+3	+4

Payoffs to Player A

B chooses \ A chooses	YES	NO
YES	+6	+4
NO	+7	−2

Payoffs to Player B

The entry in each cell of the table is the payoff, in points. For example, in payoffs to Player A, the table says that if both players choose response "YES," then Player A will receive +6 points. The other table, for Player B, shows that if both say "YES," Player B will also receive +6 points.

Such a game can sometimes be analyzed by considering all simple alternatives. Suppose, to start off, that A chooses YES. Then he will receive either +6 or +3, depending upon what B does, and B will receive either +6 or +7. Presumably, in this case, B will choose NO, so as to receive 7 points. In this case, A receives only 3 points.

Now we can imagine that A shifts to response NO, so as to receive +4 points. However, if he does this, then B received −2 points, and we must expect B to shift to YES. This, in turn, leaves A saying "NO" and B saying "YES," so A receives only 1 point, and presumably would shift back to YES so as to get 6 points.

Since no simple strategy arrives at a definite solution, it is possible that subject A says "YES" with probability a, and says "NO" with probability $1-a$; also, B says "YES" with probability b, and "NO" with probability $1-b$. Assuming they respond independently, the probability that they both say "YES" is ab. It is possible, by slightly advanced mathematical methods, to determine the optimal choice of a to maximize the payoff to subject A, and the optimal choice of b to maximize the payoff to subject B. If both optimal choices are consistent, this is called the mathematical "solution" of the game. The solution of the above game is $a = 6/7$, $b = 1/6$.

It has not generally been found that subjects, when actually playing such simple games, arrive at the optimal solution. On the other hand, it is natural to expect that after a large number of trials, subjects should at least approximate the solution.

At any rate, the analysis by game theory shows some of the ramifications of interaction between people, when the payoff to each person depends upon the responses of both. Clearly, the behavior to be expected depends not only on the personalities of the people, and the nature of the rewards and punishments, but also upon the simple arrangement of the payoffs and how they depend upon behavior.

PROCEDURE

Three students form an experimental group consisting of two players, A and B, and a referee. The two players sit facing away from each other, and each has in front of him a card showing the large words YES and NO. Each player carefully reads "Player's Instructions."

The referee chooses one of the games, 1–4, and gives each player a copy of the subject's payoff schedule for that game. (Be sure both subjects have the same game.) The referee sits where he can easily see the YES–NO cards of both players.

For Trial 1, each player indicates his response secretly by pointing to YES or NO on his card. The referee records the two responses on his data sheet. He then looks up on the Referee's Payoff Schedule the payoffs given the two subjects, and announces them. For example, "A gets 4 points, B gets 2 points." Then the players are free to make their choices for Trial 2, and the game continues.

Players make 100 responses for each of the four problems. It is usually possible to allow the players to take as much time as they like.

In some games, both players may agree that they will continue to make exactly the same response for the remainder of the 100 trials of the game. They may be allowed to stop, but the referee should be certain that *both* players have made a definite decision and will play mechanically from then on, before stopping and going on to the next game.

The instructor should arrange for the games to be played in different orders by different subgroups of his class, doing as well as possible in counterbalancing order effects.

RESULTS

There are four possible combinations of response on a given trial by a pair of players, YES–YES, YES–NO, NO–YES, and NO–NO. They are designated Outcomes 1–4 as follows:

		Player A	
		YES	NO
Player B	YES	1	2
	NO	3	4

First, for each problem and each group, tabulate the frequency of outcomes, 1, 2, 3, and 4 for each block of 25 trials.

The games are analyzed as follows:

Game 1. Player A always prefers to make response No, no matter what Player B does. Player B, having learned this, should make response No himself so as to get the highest score he can.

Solution: NO–NO (Outcome 4). Score all groups on the frequency of Outcome 4, over blocks of 25 trials, and plot a "learning curve" for the class.

Game 2. This game has no simple solution. If Player A chooses YES, then Player B's best response is also YES (3 points for B). But if B plays YES then A should play NO (4 instead of only 2 points). When A plays NO, B should also play NO. Thus the game goes around in circles. The expectation is that all four outcomes, 1, 2, 3, and 4, should occur.

Solution: Both players play half YES and half NO at random. The frequencies of all four outcomes, 1,2,3, and 4, should be plotted to see whether all are above zero.

Game 3. Player A's points depend only on what B does. However, A can influence B. If A always chooses response YES, then he makes it profitable for B to choose YES, and that is the situation that gives A three points.

Solution: Both players play YES, Outcome 1. (Note that some Player A subjects may not notice the possibility, and therefore play response NO, in which case Player B can profit.)

Game 4. In this game Player B's responses have no effect on either player's outcome. Naturally, Player A chooses NO to give himself 2 points. It does not matter what Player B does, but it is possible that some *symbolic* responses may occur.

Solution: Player A chooses response 2. This is Outcome 2 or 4. Add the frequencies of these two outcomes and draw a graph. Also, determine whether 2 or 4 is more frequent, even though they yield the same number of points.

PLAYER'S INSTRUCTIONS:

"In these games you are to try to accumulate the maximum number of points possible. Your score will be compared to that of other players in the *SAME* group. That is, if you are in Group A, you will be competing against others in Group A. Your partner will be competing in Group B. The number of points that you will be able to accumulate will depend on what your partner does, BUT THE NUMBER OF POINTS HE GETS IS IRRELEVANT TO YOUR WINNING OR LOSING. In each game your points will be determined by the payoff schedule for that particular game. The referee will inform you of the number of points you have acquired on a trial immediately after you have responded.

"For the series of four games you will keep the same partner and you will always be in the same group, either A or B. You and your partner must be of the same sex.

"You have a response card which has NO on one side, and YES on the other. When the referee says "O.K." you are to show the side of the card that indicates your response to the referee without your partner seeing the response. A back-to-back seating arrangement will be best. YOU ARE NOT TO TALK AT ANY TIME DURING A GAME. You may respond with either a "YES" or a "NO" on each trial (a trial is signaled when the referee says "O.K.").

"The payoff matrix for each game will be given to you just before each game by the referee. After you receive the payoff matrix YOU ARE NOT TO TALK UNTIL THE GAME IS OVER."

REFERENCE

Thibaut, J. W., & Kelley, H. H. *The social psychology of groups.* New York: Wiley, 1959; See especially Chapter 7.

YES

ON

GAME 1

		Player A's Points Player A's Response: YES	NO
Player B's Response	YES	2	4
	NO	2	3

		Player B's Points Player A's Response: YES	NO
Player B's Response	YES	6	2
	NO	4	3

GAME 2

Player A's Points

		Player A's Response: YES	Player A's Response: NO
Player B's Response	YES	2	4
	NO	3	1

Player B's Points

		Player A's Response: YES	Player A's Response: NO
Player B's Response	YES	3	1
	NO	1	3

GAME 3

Player A's Points

		Player A's Response: YES	Player A's Response: NO
Player B's Response	YES	3	3
	NO	1	1

Player B's Points

		Player A's Response: YES	Player A's Response: NO
Player B's Response	YES	3	1
	NO	2	4

GAME 4

Player A's Points

		Player A's Response: YES	Player A's Response: NO
Player B's Response	YES	1	2
	NO	1	2

Player B's Points

		Player A's Response: YES	Player A's Response: NO
Player B's Response	YES	7	0
	NO	7	0

Cell Definitions

		Player A's Response	
		YES	NO
Player B's Response	YES	1	2
	NO	3	4

	Points			Points	
	Player A	Player B		Player A	Player B
Game 1			Game 3		
Cell 1	2	6	Cell 1	3	3
Cell 2	4	2	Cell 2	3	1
Cell 3	2	4	Cell 3	1	2
Cell 4	3	3	Cell 4	1	4
Game 2			Game 4		
Cell 1	2	3	Cell 1	1	7
Cell 2	4	1	Cell 2	2	0
Cell 3	3	1	Cell 3	1	7
Cell 4	1	3	Cell 4	2	0

Cell Definitions

		Player A's Response	
		YES	NO
Player B's Response	YES	1	2
	NO	3	4

	Points			Points	
	Player A	Player B		Player A	Player B
Game 1			Game 3		
Cell 1	2	6	Cell 1	3	3
Cell 2	4	2	Cell 2	3	1
Cell 3	2	4	Cell 3	1	2
Cell 4	3	3	Cell 4	1	4
Game 2			Game 4		
Cell 1	2	3	Cell 1	1	7
Cell 2	4	1	Cell 2	2	0
Cell 3	3	1	Cell 3	1	7
Cell 4	1	3	Cell 4	2	0

Referee's Payoff Schedule

Cell Definitions

		Player A's Response	
		YES	NO
Player B's Response	YES	1	2
	NO	3	4

	Points			Points	
	Player A	Player B		Player A	Player B
Game 1			Game 3		
Cell 1	2	6	Cell 1	3	3
Cell 2	4	2	Cell 2	3	1
Cell 3	2	4	Cell 3	1	2
Cell 4	3	3	Cell 4	1	4
Game 2			Game 4		
Cell 1	2	3	Cell 1	1	7
Cell 2	4	1	Cell 2	2	0
Cell 3	3	1	Cell 3	1	7
Cell 4	1	3	Cell 4	2	0

Cell Definitions

		Player A's Response	
		YES	NO
Player B's Response	YES	1	2
	NO	3	4

	Points			Points	
	Player A	Player B		Player A	Player B
Game 1			Game 3		
Cell 1	2	6	Cell 1	3	3
Cell 2	4	2	Cell 2	3	1
Cell 3	2	4	Cell 3	1	2
Cell 4	3	3	Cell 4	1	4
Game 2			Game 4		
Cell 1	2	3	Cell 1	1	7
Cell 2	4	1	Cell 2	2	0
Cell 3	3	1	Cell 3	1	7
Cell 4	1	3	Cell 4	2	0

Referee's Instructions and Data Sheet

You are to ensure that there is no communication either between the two players, or between yourself and the players, except for signaling a trial and announcing the payoffs. Your task is to signal each trial by saying "O.K." to record each player's response ("YES" or "NO"), and to announce the payoffs as dictated by the payoff schedule for the response combination. Repeat until all 100 trials have been completed.

REFEREE IS TO MARK RESPONSE OF EACH PLAYER ON EVERY TRIAL

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
1	___	___	19	___	___	37	___	___	55	___	___
2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	_______
	Player B	_______
NO	Player A	_______
	Player B	_______

Referee's Instructions and Data Sheet

You are to ensure that there is no communication either between the two players, or between yourself and the players, except for signaling a trial and announcing the payoffs. Your task is to signal each trial by saying "O.K." to record each player's response ("YES" or "NO"), and to announce the payoffs as dictated by the payoff schedule for the response combination. Repeat until all 100 trials have been completed.

REFEREE IS TO MARK RESPONSE OF EACH PLAYER ON EVERY TRIAL

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
1	___	___	19	___	___	37	___	___	55	___	___
2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	________
	Player B	________
NO	Player A	________
	Player B	________

Referee's Instructions and Data Sheet

You are to ensure that there is no communication either between the two players, or between yourself and the players, except for signaling a trial and announcing the payoffs. Your task is to signal each trial by saying "O.K." to record each player's response ("YES" or "NO"), and to announce the payoffs as dictated by the payoff schedule for the response combination. Repeat until all 100 trials have been completed.

REFEREE IS TO MARK RESPONSE OF EACH PLAYER ON EVERY TRIAL

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
1	___	___	19	___	___	37	___	___	55	___	___
2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	______
	Player B	______
NO	Player A	______
	Player B	______

Referee's Instructions and Data Sheet

You are to ensure that there is no communication either between the two players, or between yourself and the players, except for signaling a trial and announcing the payoffs. Your task is to signal each trial by saying "O.K." to record each player's response ("YES" or "NO"), and to announce the payoffs as dictated by the payoff schedule for the response combination. Repeat until all 100 trials have been completed.

REFEREE IS TO MARK RESPONSE OF EACH PLAYER ON EVERY TRIAL

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
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2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	______
	Player B	______
NO	Player A	______
	Player B	______

EXPERIMENT

19 TWO-PERSON GAMES: II. The Prisoner's Dilemma

PROBLEM

In a classic story two prisoners, held on suspicion of burglary, are interrogated separately by the District Attorney. He tells each this:

"You are a reasonable man, so I expect you to confess to burglary. In fact, our evidence is insufficient. If neither of you confess, I can get you convicted of breaking and entering, and a one-year sentence. If you both confess, you will both be convicted of burglary and get a 10-year sentence.

"However, if you confess and your partner does not, I will see that you get off free. Therefore, if your partner does not confess, you are better off to confess. You get off scot free, instead of one year in prison for breaking and entering.

"If your partner confesses, and you do not, we will throw the book at you. You can count on conviction with his confession, and we will get you for at least 12 years. If your partner confesses and you also confess, then we will settle for a 10-year sentence. Therefore, if your partner confesses, you are better off to confess.

"No matter whether he confesses or not, you are better off to confess. Think it over."

Next morning the District Attorney picked up both confessions from the rational suspects, who both went to prison for 10 years. They both were rational, though of course both could have obtained a 1-year sentence instead.

How is it that rational behavior, correctly calculated to bring each man the best possible outcome, resulted in a bad and avoidable outcome for both?

The prisoner's dilemma is a particular form of two-person, non-zero-sum game. In its simplest form, it can be played just like the games in the previous experiment.

PROCEDURE

Three students form an experimental group, Players A and B and a referee. Be sure that each pair of players consists of two women or two men. The players sit facing away from each other, and each has his YES–NO card.

If the experimental group is to work under Condition I (see Appendix D) the two subjects open the instruction sheet under Condition I, and read it carefully. The two players and referee may discuss the instructions and ask the instructor for clarification, but not when the two conditions are together in the room. If the experimental group is to run under Condition II, they open the appropriate instructions. The referee should ensure that the players have *not* read the instructions of the other Condition.

The procedure is just as in Game Experiment I except that the referee is not permitted to stop the game before all 100 decisions are made.

RESULTS

For every group the solution NO–NO is "rational," though YES–YES would result in higher payoff. Plot the proportion of YES and NO responses, by 50-trial blocks, plotting Conditions I and II as separate lines.

Test the difference between Conditions I and II statistically. Each experimental group (pair of players) is a single independent observation. Therefore, for each experimental group count up the total YES responses made by both members as an index of degree of cooperation. See if the degree of cooperation is different in Conditions I and II. Also, see if it is different for men and women.

For more detailed analysis it is possible to count the proportion of times Player A says YES on a trial immediately after Player B said NO, and compare this with the proportion of times A said YES after B said YES. This difference measures the effect of B's attempts to enlist A's cooperation. (Of course, you should also measure A's effect on B, the same way.)

Notice that one player may say YES for several trials, even when the other says NO. What is he trying to accomplish by this?

Students who have been players should discuss their strategies after the experiment, in an attempt to determine how different people view this task.

GAME MATRIX

Player A's Points

		Player A's Response: YES	Player A's Response: NO
Player B's Response	YES	5	6
	NO	−10	−8

Player B's Points

		Player A's Response: YES	Player A's Response: NO
Player B's Response	YES	5	−10
	NO	6	−8

Referee's Instructions and Data Sheet

You are to ensure that there is no communication either between the two players, or between yourself and the players, except for signaling a trial and announcing the payoffs. Your task is to signal each trial by saying "O.K." to record each player's response ("YES" or "NO"), and to announce the payoffs as dictated by the payoff schedule for the response combination. Repeat until all 100 trials have been completed.

REFEREE IS TO MARK RESPONSE OF EACH PLAYER ON EVERY TRIAL

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
1	___	___	19	___	___	37	___	___	55	___	___
2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	_______
	Player B	_______
NO	Player A	_______
	Player B	_______

Referee's Instructions and Data Sheet

You are to ensure that there is no communication either between the two players, or between yourself and the players, except for signaling a trial and announcing the payoffs. Your task is to signal each trial by saying "O.K." to record each player's response ("YES" or "NO"), and to announce the payoffs as dictated by the payoff schedule for the response combination. Repeat until all 100 trials have been completed.

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Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
1	___	___	19	___	___	37	___	___	55	___	___
2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	______
	Player B	______
NO	Player A	______
	Player B	______

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2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(*Continued*)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	_______
	Player B	_______
NO	Player A	_______
	Player B	_______

Referee's Instructions and Data Sheet

You are to ensure that there is no communication either between the two players, or between yourself and the players, except for signaling a trial and announcing the payoffs. Your task is to signal each trial by saying "O.K." to record each player's response ("YES" or "NO"), and to announce the payoffs as dictated by the payoff schedule for the response combination. Repeat until all 100 trials have been completed.

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1	___	___	19	___	___	37	___	___	55	___	___
2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	________
	Player B	________
NO	Player A	________
	Player B	________

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Trial No.	Player No.		Trial No.	Player No.		Trial No.	Player No.		Trial No.	Player No.	
	A	B		A	B		A	B		A	B
1			19			37			55		
2			20			38			56		
3			21			39			57		
4			22			40			58		
5			23			41			59		
6			24			42			60		
7			25			43			61		
8			26			44			62		
9			27			45			63		
10			28			46			64		
11			29			47			65		
12			30			48			66		
13			31			49			67		
14			32			50			68		
15			33			51			69		
16			34			52			70		
17			35			53			71		
18			36			54			72		

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	________
	Player B	________
NO	Player A	________
	Player B	________

Referee's Instructions and Data Sheet

You are to ensure that there is no communication either between the two players, or between yourself and the players, except for signaling a trial and announcing the payoffs. Your task is to signal each trial by saying "O.K." to record each player's response ("YES" or "NO"), and to announce the payoffs as dictated by the payoff schedule for the response combination. Repeat until all 100 trials have been completed.

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5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	_______
	Player B	_______
NO	Player A	_______
	Player B	_______

Referee's Instructions and Data Sheet

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3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
7	___	___	25	___	___	43	___	___	61	___	___
8	___	___	26	___	___	44	___	___	62	___	___
9	___	___	27	___	___	45	___	___	63	___	___
10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	_______
	Player B	_______
NO	Player A	_______
	Player B	_______

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2	___	___	20	___	___	38	___	___	56	___	___
3	___	___	21	___	___	39	___	___	57	___	___
4	___	___	22	___	___	40	___	___	58	___	___
5	___	___	23	___	___	41	___	___	59	___	___
6	___	___	24	___	___	42	___	___	60	___	___
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10	___	___	28	___	___	46	___	___	64	___	___
11	___	___	29	___	___	47	___	___	65	___	___
12	___	___	30	___	___	48	___	___	66	___	___
13	___	___	31	___	___	49	___	___	67	___	___
14	___	___	32	___	___	50	___	___	68	___	___
15	___	___	33	___	___	51	___	___	69	___	___
16	___	___	34	___	___	52	___	___	70	___	___
17	___	___	35	___	___	53	___	___	71	___	___
18	___	___	36	___	___	54	___	___	72	___	___

(Continued)

Referee's Instructions and Data Sheet (*Continued*)

Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B	Trial No.	Player No. A	Player No. B
73	___	___	80	___	___	87	___	___	94	___	___
74	___	___	81	___	___	88	___	___	95	___	___
75	___	___	82	___	___	89	___	___	96	___	___
76	___	___	83	___	___	90	___	___	97	___	___
77	___	___	84	___	___	91	___	___	98	___	___
78	___	___	85	___	___	92	___	___	99	___	___
79	___	___	86	___	___	93	___	___	100	___	___

TOTAL

YES	Player A	_______
	Player B	_______
NO	Player A	_______
	Player B	_______

APPENDIX

A METHODS IN THE ANALYSIS OF DATA

For convenience in the following discussion, the activities involved in the successful completion of an experiment have been divided arbitrarily into three phases, each with a somewhat different aim.

During the first phase, the primary aim of the researcher is to devise a set of circumstances under which particular hypotheses may be tested fairly. The hypotheses themselves arise from diverse sources. Some are derived from testable implications or deductions from theory, some from generalizations or extrapolations from previous data, and, occasionally, from the merest hunch. Each experiment is done to settle some issue, to test some hypothesis, or to decide between two or more possibilities. In accomplishing this, the researcher must first be concerned with the refinement and clarification of hypotheses, the choice and careful definition of the dependent variable, the selection and mode of manipulation of the independent variable, methods for the control of irrelevant and/or confounded variables. and the specification of the control observations which would be required in order to eliminate alternative interpretations.

For example, in Experiment 16 on the serial-position effect, one possible hypothesis is that all items in the list will be equally difficult to learn, and another is that the first items will be easy by virtue of being first. Suppose that, in fact, the first few items are learned in fewer trials than the rest; will this support the second hypothesis? Not if there is any reason to believe that the first few nonsense words are intrinsically easier (say, easier to spell) than the others. This would be a *confounded* variable, and would make a positive experimental result uninterpretable. Another experimental error would be to give the subjects more time to study the first items in the list, and less time on the other items. In fact, as can be seen, every such variable should be held constant from item to item so that we can draw conclusions about serial position.

Another decision that must be made concerns what measurements are to be taken. In Experiment 16, we could ask the subjects after they learn the list, which items seemed to be most difficult. We might measure the loudness of voice with which they respond. In the actual experiment, however, we measure the proportion of times the subject gives an item correctly. Percentage correct was chosen as the most appropriate dependent variable to answer the theoretical question chosen.

Once the situation is chosen, confounded variables have been controlled, and the dependent variable defined and chosen, then the experiment is performed. A detailed and organized record must be kept of what the experimenter did on each trial, and what responses the subject produced. This is the second phase.

When the conditions appropriate for a fair test have been selected and the desired observations made, the experiment moves into a third phase. During this phase the aim is to organize and present the obtained observations as evidence for or against the hypothesis under test. This phase ends with a conclusion as to whether the hypothesis was confirmed or contradicted by the obtained evidence. While pursuing this goal, the experimenter must be concerned with two major classes of procedure: descriptive statistics and inferential statistics.

DESCRIPTIVE STATISTICS

The collection, measurement and recording of observations are but a first step in the analysis of data. At this point, the measurements are often referred to as raw data, a term that aptly conveys a sense of incompleteness. Typically, one is faced with substantial *variability* among the observations, i. e., they differ one from another with regard to the measured property. Consequently, the researcher routinely encounters the task of summarizing and reducing the raw data to a more manageable and understandable form. Methods designed for this purpose are referred to collectively as *descriptive statistics.*

Frequency Tables. The unorganized listing of the measurements, or *scores,* is called an *array,* an example of which is given in Table 3.

In order to present these same scores in such a way that the information in them may be seen more easily, a frequency table such as Table 4 may be constructed.

Table 3

An Array of the Cumulative Grade Point Averages (CGPA) for Thirty Students

Student No.	CGPA	Student No.	CGPA	Student No.	CGPA
1	3.2	11	3.2	21	2.8
2	2.6	12	2.8	22	2.2
3	3.0	13	2.6	23	3.2
4	2.4	14	2.4	24	2.4
5	3.4	15	3.6	25	2.0
6	2.8	16	2.8	26	2.6
7	2.8	17	3.0	27	3.0
8	2.6	18	2.4	28	3.0
9	2.2	19	2.6	29	2.8
10	3.0	20	3.4	30	3.2

Table 4

A Frequency Table of the Scores Presented in Table 3

Score (X)	Frequency (f)	$f(X)$
3.6	1	3.6
3.4	2	6.8
3.2	4	12.8
3.0	5	15.0
2.8	6	16.8
2.6	5	15.0
2.4	4	9.6
2.2	2	4.4
2.0	1	2.0
	$N = 30$	Sum of $f(X) = 86.0$

Note that certain symbols have been introduced. Frequency (f) indicates the number of instances of that particular score or set of scores. Number (N) indicates the total number of observations and is equivalent to the number of subjects employed multiplied by the number of observations per subject. The symbol $f(X)$ indicates the result of multiplying a score by the frequency with which it appears. The sum of $f(X)$ is equal to the sum of all the N scores.

At times the score values may vary so widely that an inconveniently long table would result. For example, consider the array of scores, correct responses in a learning experiment, in Table 5.

Table 5

An Array of Learning Scores

16	30	35	46	36	45	47	36	63	41
31	34	33	41	43	34	57	51	47	25
28	32	37	30	23	26	38	43	37	29
40	39	22	44	42	42	39	38	27	45

The variety of score values ranging from the lowest (16) to the highest (63) is so large that our table would be unwieldy if we tallied each score value separately, from 16 through 63. In such cases the score values should be grouped into larger classes, e. g., the class 45–49, which would include scores of 45, 46, 47, 48, and 49 within its *class interval.* In selecting appropriate classes, three things should be kept in mind. First, the classes should be of equal width, e. g., 45–49, 50–54, and 55–59. Second, the width of the classes determines the number of classes. If the classes are too wide, the table may be very compact, but not very informative, e. g., 15–39 and 40–64. To strike a balance between compactness and loss of information it is suggested as a rule of thumb that about ten classes be employed. Third, for certain computational procedures it is convenient to have a whole number at the midpoint of the class interval. Thus, it is advisable to use a class interval with an odd number of included values, e. g., 3–5, whose midpoint is 4, rather than 3–6, whose midpoint is 4.5.

In the case of the learning data, ten intervals, five units wide, would be suitable. To make the frequency table, we list the class intervals and record the number of scores falling within each interval (Table 6).

Table 6

Frequency Table of Learning Scores

Class intervals	Frequency f	Midpoints X	$f(X)$
60–64	1	62	62
55–59	1	57	57
50–54	2	52	104
45–49	5	47	235
40–44	7	42	294
35–39	9	37	333
30–34	7	32	224
25–29	5	27	135
20–24	2	22	44
15–19	1	17	17
	$N = 40$	Sum of $f(X)$ =	1505

It should be observed that, when class intervals are employed, the midpoint is used to describe the scores falling in that interval. A slight distortion of the original data is thus introduced as the cost of a more compact description of the entire array. If the distribution of scores within the interval is symmetric about the midpoint, the distortion is minimized.

Frequency Polygons. The data may also be presented in graphic form by a frequency polygon. The advantages in both frequency tables and frequency polygons presenting large numbers of observations are that one may easily see the number of scores of each kind, the features of grouping, irregularity, and symmetry are more visible, and comparisons among groups are facilitated.

A frequency polygon, such as the one shown in Fig. 4, is constructed as follows:

1. Draw the abscissa (horizontal or X axis) and ordinate (vertical or Y axis).
2. Mark off the X values from the frequency table along the horizontal axis. When an odd number is used for the class interval, the X values are the middle scores in each interval.
3. Mark off distances on the vertical axis to represent frequencies.
4. Label both axes.
5. Place a dot above each X value at a height that will represent the frequency of that score (or frequency of scores in that class interval) in the frequency table.
6. Connect the dots with straight lines, carrying the line to zero frequency when no scores were observed at a particular value.
7. Give the graph a suitable title.

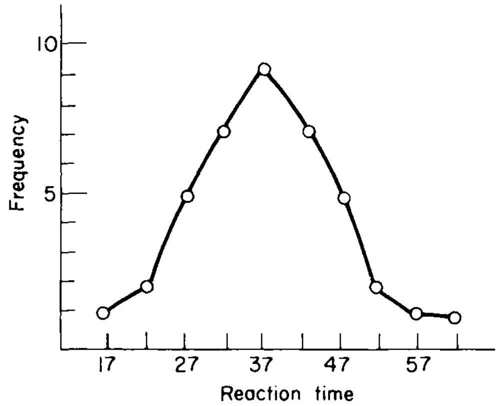

Fig 4 Frequency polygon of the data in Table 6.

Forms of frequency polygons. Frequency polygons from behavioral research can generally be classified into one of two types: "counting" or "waiting-time" distributions.

A counting distribution, ideally, is the measurement of something that may be more or less numerous within a period of observation, depending upon the combined influence of many random factors. For example, the total number of bar presses, collected over successive 5-minute periods, varies from period to period. Since the total frequency is counted each trial, the distribution will be a counting distribution. It will usually be symmetrical about a central point, most observations being near the center of the distribution.

A waiting-time distribution, ideally, is the measurement of how long one must wait for an event to occur, when the length of wait is subject to many random influences. In some learning theories, for example, mastery of a single particular item is a random event. Until learning occurs, the subject makes errors at some rate depending upon the experimental arrangement. In a simple waiting-time experiment, low scores are the most frequent, and the higher scores (longer waits) are less and less frequent, so that the distribution is highly "skewed."

Typical distributions are shown in Fig. 5.

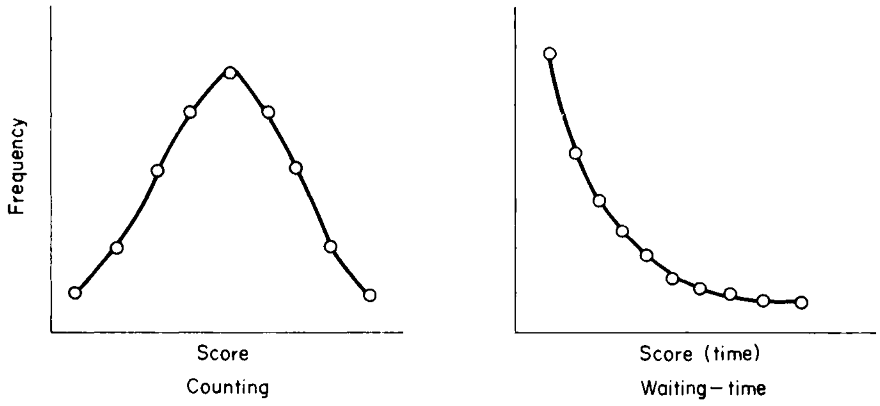

Fig 5 Examples of counting and waiting-time distributions.

One particular variety of symmetrical frequency polygon should be mentioned, the *normal frequency function.* A mathematical equation may be written which yields a family of bell-shaped curves, various members of the family being broader or narrower in range, or more or less peaked, depending on the numbers entered into the equation. The special significance of this particular mathematical construction above others is this: In the case of many biological and psychological measurements (e.g., height, intelligence test scores, anthropomorphic measurements), the distributions resemble the normal frequency curve, especially when large numbers of observations have been assembled. If a large number of random factors interact, they result in a variable end product that is distributed as the normal frequency function. The similarity of empirical distributions to the mathematical ones has been taken to mean that at least one component of empirical measurements is derived through just such an interaction of random factors.

Histograms. A histogram, or bar diagram, should be used rather than a frequency polygon in cases where the dependent variable is merely a set of categories, rather than points on an ordered dimension. The frequency observed in each category is then represented in the length of the bar. The bars for adjacent categories are not connected by lines as was done for the frequency polygon. An example of such a histogram, employed to present the frequency with which various religious affiliations appear in a sample of college students is given in Fig. 6.

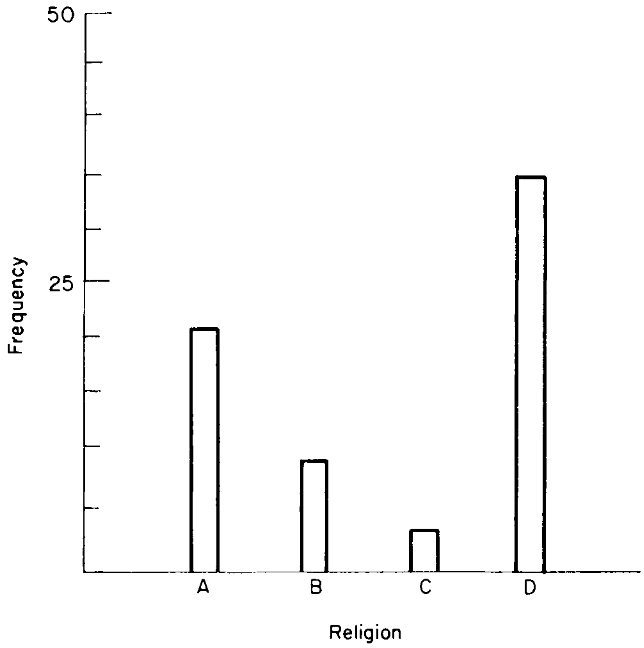

Fig 6 The frequency of various religious affiliations of college students.

The bar diagram would also be the appropriate choice to represent the data from an experiment in which measurements of the dependent variable are taken under several categories of independent variable. For example, in plotting the data from experiment 15 the number of items recalled would be represented by a bar of proper length, one bar for each of the types of intervening items used—animals, birds, fruits, colors, cities, and insects.

Cumulative Records. To make clear how the cumulative record is constructed, let us assume that a rat being reinforced for a bar-pressing response by small pellets of food makes the following numbers of responses during the first several successive minutes of training: 2, 4, 5, 8, 10, 12, 12, 11, 13, 13.

As a first step in preparation of the cumulative record, it is helpful to prepare a table such as Table 7.

Table 7

Frequencies and Cumulative Frequency of Reinforced Bar-Pressing Responses

Minute	Responses	Cumulative responses
1	2	2
2	4	6
3	5	11
4	8	19
5	10	29
6	12	41
7	12	53
8	11	64
9	13	77
10	13	90

The first column of Table 7 indicates the minute during which observations were made, the second shows the number of responses during the successive minutes, and the third indicates the total number of responses made from the beginning of the observation up through each of the successive minutes of observation. That is, during the first minute the rat made two responses, so by the *end* of the first minute he had made just two responses. During the second minute he made four responses, so by the *end* of the second minute he made 2 + 4, or 6 responses. Notice that one can always obtain the number in row n of the cumulative response column by adding the number in row $n - 1$ of the cumulative response column to the number of responses in row n. That is, in row eight of Table 7, 64 = 53 + 11.

Now the cumulative record can be plotted graphically by laying off the minutes along the X axis and connecting the points representing cumulative frequencies above each of the successive minutes (Fig. 7).

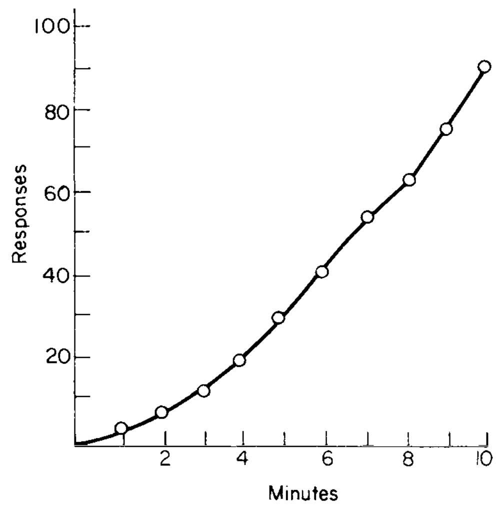

Fig 7 Cumulative frequency of reinforced bar-pressing responses.

Certain features of such a cumulative graph should be evident:

1. The curve can *never* descend. Once the rat has pressed the bar there is no way in which he can *unmake* the response. Therefore the total number of responses can never diminish.
2. Cessation of responding is represented by a line parallel to the X axis.
3. The greater the rate of responding, the closer the curve approaches the vertical.
4. Positive acceleration or increase in rate of responding is represented by a sharper slope in the curve, whereas negative acceleration or decrease in rate of responding is represented by a lessening in the slope of the curve.

Thus we notice that the rat, during the period of observation recorded above, exhibited an overall positive acceleration in rate of responding.

In general, responses in operant conditioning experiments are plotted in the form of a cumulative record. There are several advantages to this type of representation: First, the method enables one to deal conveniently with very low and very high rates of responding within the same graph. Second, such a graph can be constructed mechanically very simply and for long periods of time. Third, the method brings out clearly to visual inspection changes in rate of responding.

Measures of Central Tendency. An average of a distribution is a score which represents the center of the distribution. There are many ways of defining the center.

The *mean* is obtained by adding together all the individual scores and dividing by the total number of scores. The formula for the mean is $M = \Sigma X/N$. The student will become familiar with the symbol "Σ," which, in statistical formulas, can be read "the sum of all the." Thus the formula for the mean is read, "the sum of all the X's divided by N."

The mean can be computed directly from a frequency table by dividing the total of the $f(X)$ column by the number of scores. The formula is $M = \Sigma f(X)/N$. That is, one multiplies each score by the number of times it occurs and divides the sum of these products by N. The mean for the data in Table 4, then, is:

$$\frac{86.0}{30.0} = 2.87$$

In a grouped frequency table such as Table 6, the scores are all assumed to fall at the midpoint of the interval, and consequently each X, or midpoint, is multiplied by the number of cases in the interval. Thus the mean for Table 6 is:

$$\frac{1505}{40} = 37.6$$

The mean is best used when the distribution is symmetrical, or nearly so, since it is unduly influenced by a few very high or very low scores.

The *median,* another average, is the middle score of a group arranged in order of size. To find the median one must simply arrange the scores in order and, if there is an odd number of scores, find the middle score, or if there is an even number of scores, find the point midway between the two middle scores. In each case one finds a point which separates the upper 50% of the scores from the lower 50%. The median is especially useful as a measure of central tendency when the distribution is not symmetrical since it is not affected by a few extremely high or low scores.

The *mode* is the score occurring most frequently in the distribution. This average is not a very stable or dependable measure and is chiefly used as a rough preliminary estimate of central tendency.

When a frequency distribution is skewed, the mean, median, and mode will not have the same numerical value. The more nearly symmetrical the distribution, the more nearly will the different measures of central tendency coincide.

One can compare the various averages by considering a hypothetical distribution of incomes. Let us assume that the man with the highest salary for some reason suddenly has his salary doubled. This will have a marked increase on the mean because one of the X's in the formula $\Sigma X/N$ will be increased tremendously. However, there will be no change in the median since the middle salary will not have been changed. Likewise the mode will remain unchanged. It is interesting to note that the discrepancy between the mean and the median or mode can be used as a measure of skewness.

Measures of Variability or Dispersion. Dispersion refers to the variability of a set of scores, i.e., the extent to which the scores scatter or spread around the measure of central tendency. Dispersion can vary independently of the mean, median, and mode, and consequently two distributions could have the same averages, and yet differ considerably in variability.

The *range,* defined as the difference between the lowest and highest scores in the group, is the least complicated of the measures of variability. However, since it is based on only the two extreme scores of the group it is not very accurate and dependable, and hence is used only as a rough, preliminary estimate of dispersion. Some information about the dispersion of scores is necessary for interpretation of any individual score. We may consider an example from a typical classroom situation. Suppose you were told that you received a score of 60 on a certain test and that the class average was 50. While you could be confident that you did not fail the test, you still would not know what grade to expect unless you were given some idea of the dispersion. If you knew that the range of scores was 80, say from 18 to 98, you would expect only a "C." On the other hand, if the range of scores were 22, say from 39 to 61, you would expect an A, because your relative standing in the class would be much higher. Notice, however, that the student who earned the score of 39 in the latter case might conceivably have failed the test miserably and earned a score of only 10. This would have more than doubled the *range*, and still not have affected other grades.

The *variance*, while more complicated to determine than range, is much less subject to fluctuation by virtue of extreme scores since all scores are used in the computation rather than just two.

The formula for variance (σ^2) is

$$\sigma^2 = \frac{\Sigma(X-\bar{X})^2}{N-1}$$

where X = raw scores, $\bar{X}$ = mean of scores, and N = number of scores. It reads, "the sum of the squared deviations of each score from the mean, divided by the number of scores less 1."

Consider the following hypothetical data.

X	$(X-\overline{X})$	$(X-\overline{X})^2$
14	+4	16
13	+3	9
12	+2	4
11	+1	1
11	+1	1
10	0	0
9	−1	1
9	−1	1
8	−2	4
7	−3	9
6	−4	16
$\Sigma X = 110$		$62 = \Sigma(X-\overline{X})^2$
$N = 11$		
$\overline{X} = 10$		$\sigma^2 = \frac{\Sigma(X-\overline{X})^2}{N-1} = \frac{62}{10} = 6.2$

The mean of the scores in column 1 is 10. Subtracting this mean value from each score results in the *deviations from the mean* shown in column 2. Each deviation is then squared, giving the values in column 3. Their total, 62, is entered as numerator of the equation for variance. The denominator equals eleven scores less one, or 10. Dividing, we obtain a σ^2 of 6.2.

It may be seen that the more widely a given number of scores deviates about their mean, the larger the squared deviations, the numerator, and, consequently, the variance.

Often the square root of the variance, the *standard deviation*, is given rather than σ^2. In our case, this value is 2.49.

INFERENTIAL STATISTICS

Like the toss of a coin, an experiment has several possible outcomes, and the coin tosser and the experimenter typically do not know which one will actually happen. However, if the coin tosser suspects that the coin is loaded, his expectations are different than if he believed the coin to be fair. More generally, the experimenter can imagine conditions (e.g., loaded vs. fair) that would lead to different experimental outcomes. He can formulate alternative hypotheses. He can test a hypothesis by comparing the outcome which the hypothesis predicts with the actual outcome of the experiment. If the outcome disagrees substantially with the predicted outcome, the hypothesis is probably wrong, and the experimenter rejects it. He infers that the hypothesis is incorrect. This section introduces some basic concepts of hypothesis testing, and describes two statistical tests that can be applied to experiments in this manual.

Consider an experiment in which a coin is tossed twice. Each toss of the coin is referred to as an observation, and each *observation* has *two* possible outcomes: H (heads), or T (tails). The two outcomes are *mutually exclusive* and *exhaustive:* the coin lands either H or T, not both (H and T are mutually exclusive); and there is no other possible outcome (H and T are exhaustive). In contrast, the two-toss *experiment* has *four* possible outcomes that are mutually exclusive and exhaustive; the first toss may land H, and the second toss may land H (Outcome HH); the first may land H, the second T (Outcome HT); the first may land T, the second H (Outcome TH); or the first toss may land T, and the second T (Outcome TT). The four possible outcomes of the two-toss experiment can be represented in the form of a tree diagram:

Outcome of Toss 1	H		T	
Outcome of Toss 2	H	T	H	T
Experimental Outcome	HH	HT	TH	TT
Probability	1/4	1/4	1/4	1/4

It seems reasonable that, if the coin is fair, the four possible experimental outcomes are equally likely to occur, i.e., that the probability of each experimental outcome is 1/4.

Interpretation: Suppose you did the two-toss experiment a large number of times, using a fair coin. If you then calculated the proportion of two-toss experiments which yielded a given experimental outcome, you would find that 1/4 of the experiments yielded two heads (HH), 1/4 yielded heads first and tails second (HT), 1/4 yielded tails first and heads second (TH), and 1/4 yielded two tails (TT).

Alternatively, we can define outcomes in terms of the *number of heads* which a two-toss experiment can possibly turn up. Here we have three rather than four possible experimental outcomes:

Outcome	Probability
Two heads (HH)	1/4
One heads (HT or TH)	2/4
No heads (TT)	1/4

Since there are two ways of getting one heads, its probability of occurrence is 1/4 + 1/4 = 2/4. If you did the two-toss experiment many times, using a fair coin, 2/4 of the experiments would yield one heads.

What if the coin were not fair? All the implications of this condition may not be clear at this point in our discussion, but they will become clear later on. If the coin were loaded in favor of heads, then the probability of getting two heads would be greater than 1/4. Of your large number of two-toss experiments, more than 1/4 would have yielded two heads. Also, the probability of getting one heads would be less than 2/4, and the probability of getting no heads would be less than 1/4. If the coin were loaded in favor of tails, then the probability of getting two heads would be less than 1/4; the probability of getting one heads would be less than 2/4; and the probability of getting no heads would be greater than 1/4. Let us explain these implications by analyzing the two-toss experiment from a slightly different viewpoint. Our analysis will use two rules from the theory of probability; the multiplication rule, and the addition rule.

The *multiplication rule* applies to *independent* observations. Two observations are independent if the outcome of one has no influence upon the outcome of the other. Our two-toss experiment provides one example of independence: the likelihood of getting H on one toss has a certain value which is unaffected by the outcome of the other toss. If the coin happens to be fair, there is always a 50-50 chance—a probability of 1/2—that the coin will land H on a given toss. If the first toss lands H, the probability that the second will land H remains 1/2. If the first toss lands T, the probability that the second will land H remains 1/2. The observations are independent.

We can use the multiplication rule to calculate the probability of *conjoint* ("and") outcome. Our two-toss experiment has four possible conjoint outcomes: HH, HT, TH, and TT. Our general expression for a conjoint outcome is "XY." Verbally, the multiplication rule says that the probability of getting a conjoint outcome XY is equal to the probability of X, multiplied by the probability of Y, provided X and Y are independent. Mathematically,

$$P(XY) = P(X)P(Y)$$

where $P(XY)$ is the probability of conjoint outcome, X and Y
$P(X)$ is the probability of X
$P(Y)$ is the probability of Y

In our two-toss experiment with a fair coin, $P(\text{H}) = 1/2$, and $P(\text{T}) = 1/2$. Let us use the multiplication rule to calculate the probabilities of our possible experimental outcomes, on the assumption that $P(\text{H}) = P(\text{T}) = 1/2$:

Outcome	Probability
HH	$P(\text{HH}) = P(\text{H})P(\text{H}) = (1/2)(1/2) = 1/4$
HT	$P(\text{HT}) = P(\text{H})P(\text{T}) = (1/2)(1/2) = 1/4$
TH	$P(\text{TH}) = P(\text{T})P(\text{H}) = (1/2)(1/2) = 1/4$
TT	$P(\text{TT}) = P(\text{T})P(\text{T}) = (1/2)(1/2) = 1/4$

The *addition rule* applies to disjoint ("or") outcomes, e.g., the outcome "H or T." Our general expression for a disjoint outcome is "$X + Y$." Verbally the addition rule says that the probability of getting a disjoint outcome $X + Y$ is equal to the probability of X, plus the probability of Y. Mathematically,

$$P(X + Y) = P(X) + P(Y)$$

In our two-toss experiment with $P(\text{H}) = P(\text{T}) = 1/2$ the probability of getting H or T on a single toss is $P(\text{H + T}) = P(\text{H}) + P(\text{T}) = 1/2 + 1/2 = 1$. On a given toss, we are sure to get heads or tails.

Let us calculate the probabilities of getting two heads, one heads, and no heads in the two-toss experiment with a fair coin.

Outcome	Probability
Two heads (HH)	From the multiplication rule, $P(\text{HH}) = 1/4$
One heads (HT or TH)	From the multiplication rule, $P(\text{HT}) = 1/4$ and $P(\text{TH}) = 1/4$. Now we want to calculate the probability of the disjoint outcome "HT or TH," i.e., the probability of getting heads on the first toss and tails on the second, or tails on the first toss and heads on the second. From the addition rule, $P(\text{HT + TH}) = P(\text{HT}) + P(\text{TH}) = 1/4 + 1/4 = 2/4$
No heads (TT)	From the multiplication rule, $P(\text{TT}) = 1/4$

The probabilities of these three outcomes can also be found by expanding the binomial expression $(P + Q)^N$. The variables in this expression are defined below.

P: The probability that any one observation will yield one particular outcome. Here, let P be the probability that the coin will land heads.

Q: The probability that any one observation will yield the only other possible outcome. Here, Q is the probability that the coin will land tails.

N: The number of observations. Here, N is the number of tosses.

In our experiment the coin is tossed twice, so the binomial is written $(P + Q)^2$. Expanding,

$$(P + Q)^2 = (P + Q)(P + Q) = P^2 + 2PQ + Q^2$$

The expanded binomial has three terms, each corresponding to one possible outcome of the two-toss experiment. The first term, P^2, corresponds to the outcome "two heads and no tails." The second term corresponds to "one heads and one tails." The third term corresponds to "no heads and two tails." The key to this correspondence can be found by looking at the terms and their exponents. Term P^2 is read "two heads," PQ is read "one heads and one tails," and Q^2 is read "two tails." The number that appears before each term of the expansion is called the coefficient of that term. Here, the coefficients are 1, 2, and 1. *The term and its exponent identify the outcome, and the coefficient expresses the number of ways in which that outcome can occur.* There is only one way in which a two-toss experiment can yield two heads: the first toss must land heads, and the second must land heads. By the multiplication rule, the probability of its landing heads on the first toss *and* heads on the second is $PP = P^2$. There is only one way in which a two-toss experiment can yield no heads: the coin must land tails on the first toss, *and* tails on the second. By the multiplication rule, the probability of its landing tails on the first toss and tails on the second is $QQ = Q^2$. Finally, there are two ways in which a two-toss experiment can yield one heads: heads on the first toss and tails on the second, or tails on the first and heads on the second. By the multiplication rule, the probability of its landing heads on the first toss and tails on the second is PQ. By the same rule, the probability of its landing tails first and heads second is $QP = PQ$. By the addition rule, the probability of its landing heads first and tails second, *or* tails first and heads second, is $(PQ) + (PQ) = 2PQ$.

If we assume that the coin is fair, we can set $P = Q = 1/2$. Substituting these values into the expansion, we get the following probabilities for the three possible outcomes:

Outcome	Probability
Two heads (HH)	$P^2 = (1/2)^2 = 1/4$
One heads (HT or TH)	$2PQ = 2(1/2)(1/2) = 2/4$
No heads (TT)	$Q^2 = (1/2)^2 = 1/4$

Exercise 1: Suppose the coin were loaded in favor of heads, such that $P = .6$, and $Q = .4$. In a two-toss experiment what is the probability of getting (a) two heads, (b) one heads, (c) no heads?

Exercise 2: Use (a) a tree diagram, and (b) the binomial expansion to show that in a *three-toss* experiment with a fair coin, the probability of getting exactly two heads and one tails is 3/8.

In the preceding examples it would have been impossible to calculate the probabilities of the various outcomes without assigning numerical values to P and Q. When we did, we were stating a hypothesis. The expression $P = Q = 1/2$ is simply a mathematical expression of the hypothesis that the coin is fair, i.e., unbiased. By assuming that this hypothesis was true, we were able to calculate the probability of each possible outcome of our experiment. Any hypothesis that allows us to do so is called a *null hypothesis*, written H_0. If the actual experimental outcome is quite improbable, we conclude that H_0 is false. Let us illustrate this hypothesis testing procedure.

Suppose you have a chance to buy a coin that is alleged to be loaded. The coin's owner tries to persuade you that it really is loaded by performing an experiment: he tosses the coin ten times, and on nine of the ten tosses it lands on the same side. You find this demonstration impressive, but not entirely persuasive. It occurs to you that even a perfectly fair coin, tossed ten times, *could* land on the same side nine, or even ten times. That is, you and the owner have two different hypotheses which can be written as follows:

H_0: $P = Q = 1/2$ (the coin is not loaded)

H_1: $P \neq Q$ (the coin is loaded; the probability of heads is not equal to the probability of tails)

H_1 is generally called the *experimental,* or *alternative hypothesis.* Using the binomial expansion and H_0, we can calculate the probability of getting results as impressive as this, or more impressive than this. That is, we can claculate the probability of getting nine or ten like landings out of ten tosses, on the assumption that H_0 is true. If this probability is relatively small, we shall conclude that H_0 is false. We shall reject H_0, and buy this extraordinary coin. If this probability is relatively large, we shall not reject H_0, and we shall not buy this ordinary coin.

Expanding $(P + Q)^{10}$, we get

$$P^{10} + 10P^9Q + 45P^8Q^2 + 120P^7Q^3 + 210P^6Q^4 + 252P^5Q^5 + 210P^4Q^6$$
$$+ 120P^3Q^7 + 45P^2Q^8 + 10PQ^9 + Q^{10}.$$

We are interested in all outcomes involving at least nine like landings: outcomes involving ten heads, nine heads, nine tails, or ten tails. The terms which correspond to these outcomes are P^{10}, $10P^9Q$, $10PQ^9$, and Q^{10}. Substituting for P and Q the numerical values specified by H_0, and using the addition rule, we find that the probability of getting at least nine like landings is:

$$(1/2)^{10} + 10(1/2)^9(1/2) + 10(1/2)(1/2)^9 + (1/2)^{10}$$
$$= 1/1024 + 10/1024 + 10/1024 + 1/1024 = 22/1024 = .02$$

Interpretation: If H_0 is true, the probability of getting at least nine like landings out of ten tosses is very small (.02). If we did the ten-toss experiment a large number of times, only about 2% of the experiment would yield such outcomes (nine or ten like landings), if the coin were fair (if H_0 were true). Accordingly, we conclude that H_0 is false. We reject H_0 with some confidence.

We can give our confidence precise quantitative expression by introducing another interpretation of the proportion .02. Let us call any proportion obtained in this fashion α. In general, α may be interpreted as the risk of rejecting a true H_0, and is called the *level of significance.* In this particular experiment, $\alpha = .02$. This means that if we decide on the basis of this experiment that H_0 is false, there is a small chance, .02, that our decision is incorrect.

It is important to recognize that we cannot be absolutely certain that H_0 is false. For example, suppose the ten-toss experiment had turned out even more impressively than it did. The most impressive experiment we can imagine is one in which the coin, tossed N times, lands on the same side each time. The probability of getting this experimental outcome is $P^N + Q^N$, and if H_0 is true, $P^N + Q^N = (1/2)^N + (1/2)^N$. If we tossed the coin 100 times ($N = 100$), getting the same landing each time, we could reject H_0 at $\alpha = (1/2)^{100} + (1/2)^{100}$. This α is exceedingly small, but it is still greater than zero. If we decide to reject H_0, there is still a very small chance that our decision is incorrect. We are not absolutely certain that H_0 is false, because absolute certainty means a level of significance such that $\alpha = 0$.

How could we get $\alpha = 0$? Only by tossing the coin an infinite number of times, and observing that the coin landed on the same side each time, because the quantity $(1/2)^N + (1/2)^N$ approaches zero as N approaches infinity. Moreover, if we can never be absolutely certain that H_0 is false, it is obvious that we can never be certain that the alternative hypothesis, H_1, is true.

In practice, then the hypothesis tester must be willing to reject H_0 *at some level of significance greater than zero,* and the level of significance one chooses for rejecting H_0 is somewhat arbitrary. *The conventional practice is to choose 1/20 or 1/100 (the .05 or .01 level of significance).* Thus, in a two-toss experiment, where $H_0 : P = Q = 1/2$, and $H_1 : P \neq Q$, we would not reject H_0 even if both tosses landed on the same side, since

$$P^2 + Q^2 = (1/2)^2 + (1/2)^2 = 2/4 = .50$$

which is greater than $\alpha = .05$. Not having rejected H_0, could we then assert that H_0 is true? No; because the outcome of this experiment is consistent with many other null hypotheses. One such null hypothesis is

$$H_0: \quad P = .7 \quad Q = .3$$

$P^2 + Q^2 = (.7)^2 + (.3)^2 = .58$, which is also greater than $\alpha = .05$. Hence, either null hypothesis might easily be true. And in general, *failure to reject* H_0 *at some conventional level of significance cannot be taken as proof that* H_0 *is true.* For other reasons, described above, rejection of H_0 at some conventional level of significance does not prove conclusively that H_0 is false, or that H_1 is true.

The Binomial Test. The binomial test—also called the "sign" test—can be used for testing H_0 in any experiment that meets these two conditions: (1) the observations are independent, and (2) each observation can be sorted into one of two mutually exclusive and exhaustive categories, e.g., heads or tails, male or female, greater than X or less than X.

Let us identify one category by a plus sign (+), and the other by a minus sign (−). N_+ is the number of observations falling into Category +, N_- is the number of observations falling into Category −, and N is the total number of independent observations. Thus,

$$N = N_+ + N_-$$

Sometimes an observation may not fit into either of your two categories. For example, it is conceivable that in a coin-toss experiment a coin might occasionally land on edge, rather than heads or tails, creating a new Category 0. In that case, N is *not* the total number of tosses, $N_+ + N_- + N_0$. If we call Category 0 a "tie," N is the total number of observations in the experiment, excluding ties. If your data happen to include a large number of ties, you should not use the binomial test.

Generally, H_0 is that $P = Q = 1/2$. In that case there is no need to calculate the probabilities by expanding the binomial; Table 8 may be used instead. *Table 8 was constructed by the binomial expansion $(P + Q)^N$ for values of N ranging from 6 to 30, with $P = Q = 1/2$. The table presents the minimum number of like outcomes required to reject H_0 at the .10, .05, and .01 levels of significance.* For example, suppose we tossed a coin 15 times in order to test the hypothesis that the coin is fair, i.e., H_0: $P = Q = 1/2$. Our H_1: $P \neq Q$. Suppose we got 12 heads and 3 tails. Here, $N = 15$.

Entering Table 8 at Row 15, we see that 12 or more like outcomes are needed to reject H_0 at the .05 level of significance. Since we got 12 heads, we reject H_0 at $\alpha = .05$. We conclude that the coin is not fair. We cannot reject H_0 at the .01 level of significance, as we need at least 13 like outcomes to do so.

The binomial test is often used to test the H_0 that two different experimental conditions have identical effects upon behavior. Suitable data can be obtained by having each subject serve under each experimental condition, A and B, so that each subject has two scores at the end of the experiment. The N observations are obtained by subtracting each subject's B score from his A score (see Example 1, below). Another way of obtaining suitable data is to use one group of subjects under Condition A, and a separate group of subjects under Condition B, provided that each subject can be paired with one subject in the other group on some reasonable basis. In this case, the N observations are obtained by subtracting each subject's score from the score of the paired subject who served under the other condition (see Example 2, below).

Example 1: Each Subject Serves under Both Conditions. An investigator studying manual dexterity wonders whether subjects do better with the preferred than with the nonpreferred hand. In his experiment 15 right-handed subjects do a pegboard test twice—once with the preferred (right) hand, and once with the nonpreferred (left) hand. The dependent variable is the amount of time required to put all the pegs into the pegboard. The results:

	Time (seconds) using		Sign of difference
Subject No.	Preferred hand	Nonpreferred hand	(preferred − nonpreferred)
1	21	28	−
2	16	14	+
3	18	30	−
4	27	28	−
5	23	23	0
6	11	19	−
7	14	19	−
8	11	12	−
9	17	22	−
10	17	18	−
11	19	28	−
12	20	21	−
13	36	38	−
14	14	23	−
15	15	17	−

According to H_0, there is no difference between performance with the preferred hand and performance with the nonpreferred hand. Let P be the probability that a given subject will do better with the preferred hand than with the nonpreferred hand. Let Q be the probability that a given subject will do better with the nonpreferred hand than the preferred hand. Then H_0 is that $P = Q = 1/2$.

In fact, the data do not seem consistent with H_0. Subjects generally performed faster with the preferred hand (median = 17 seconds) than the nonpreferred hand (median = 22 seconds). Applying the binomial test:

Number of subjects	15
Number of ties	1
N	14
N_+	1
N_-	13

Consulting Table 8, Row 14, we see that 13 like outcomes suffice to reject H_0 at the .01 level of significance. We have 13 like outcomes. Conclusion: Reject H_0 at α = .01. Subjects performed significantly faster with the preferred hand than with the nonpreferred hand.

Example 2: Each Subject Serves under One Condition, and Is Matched with Another Subject. The investigator knows that subjects can be trained to improve their performance of the pegboard task, but wants to decide between two alternative methods of training. In one method, the practice trials are given with no rest period between trials (massed practice). In the other method, the subject is allowed to rest for 2 minutes before beginning the next practice trial (distributed practice). The investigator plans to compare the two methods by giving each subject ten trials of either massed or distributed practice. The dependent variable is the amount of time the subject takes to complete the task on Trial 10.

Twenty subjects are available for the experiment, and the investigator must decide which subjects will be tested under a given condition of practice. He knows that the subjects will differ widely in their initial skill with the pegboard task—on the very first trial some will finish very quickly, some very slowly. To equate the two groups in terms of initial skill, he gives each subject a single "matching" trial, recording the time it takes each subject to complete the task.

He uses these times to form nine matched pairs of subjects. The two remaining subjects have extremely deviant times of 9 seconds and 37 seconds, cannot be matched to any other subjects, and are therefore discarded.

Matched pair No.	Time (seconds) on matching trial		Time (seconds) on Trial 10		Sign of difference (A − B)
	Subject A	Subject B	Subject A massed	Subject B distributed	
1	19	19	15	14	+
2	15	15	14	12	+
3	21	21	11	8	+
4	17	17	14	13	+
5	14	14	10	10	0
6	20	20	10	12	−
7	28	28	25	20	+
8	18	18	13	10	+
9	19	19	18	19	−

According to H_0, there is no difference between the two conditions of practice in terms of performance on Trial 10. Let P be the probability that a given subject will do better than his matched counterpart in the other experimental condition, and let Q be the probability that he will do worse than his counterpart. Then H_0 is the $P = Q = 1/2$. Applying the binomial test:

Number of subjects	18
Number of pairs	9
Number of ties	1
N	8
N_+	6
N_-	2

Consulting Table 8 for $N = 8$, we see that eight like outcomes are needed to reject H_0 at the .05 level of significance. We have only six like outcomes. Conclusion: Do not reject H_0. Subjects given distributed practice generally performed better on Trial 10 than subjects given massed practice, but the difference was not statistically significant. Since the obtained difference could easily have arisen if H_0 were true, H_0 cannot be rejected on the basis of this experiment.

The Rank Test In many experiments involving two groups of subjects there is no reasonable, convenient way to form pairs of scores. In this case a test other than the binomial test must be used. The rank test is one of the simplest appropriate to this kind of experiment.

The first step in computing the rank test is to replace each score with a rank. To assign each score its proper rank it is helpful to begin by arranging the scores from the two groups in two separate columns. With the smallest score at the top of the column, arrange the remaining scores in order. Next, rank all the scores in a *single* series, with the smallest score in the two columns getting a rank of 1, the next getting a rank of 2, and so on. It is important to note that the two groups of scores are ranked in a single series, and not in two separate series. Thus, the smallest score in a column will not get a rank of 1, unless it happens to be the smallest score in *both* columns.

Tied scores are given identical ranks. For a given group of tied scores, the rank which each score gets is equal to the mean of the ranks which those scores would have gotten if they had not been tied. For example, if the *two* smallest scores were equal, we would give each of these scores a rank of 1.5, since $(1 + 2)/2 = 1.5$. If the *three* smallest scores were equal, we would give each of those scores a rank of 2, since $(1 + 2 + 3)/3 = 2$.

The null hypothesis states that neither group ranks higher than the other. H_1 states that one group does rank higher than the other. H_0 is tested by comparing two sums of ranks: the sum of the ranks assigned to one group *vs.* the sum of the ranks assigned to the other group. If H_0 is false, one of the two sums will be considerably smaller than the other. Consider the other. *Consider the group with the smaller sum of ranks, and call its sum of ranks "R". The smaller R is, the smaller the likelihood that* H_0 *is true.*

Table 9 presents values of R needed to reject H_0 *at the* .10, .05, *and* .01 *levels of significance. The table can be used for experiments with N subjects in each group, for values of N from* 5 *through* 20.

Note On Tied Scores: Unlike the binomial test, the rank test does not require that each observation be sorted into one of two categories. Consequently, in using the rank test tied observations are *not* excluded in figuring *N.*

Example 3: Each Subject Serves under One Condition, and Is Not Matched with Another Subject: Example 1 dealt with a hypothetical experiment in which subjects performing a pegboard test did significantly better with the preferred hand than with the nonpreferred hand. Although the difference was statistically significant at $\alpha = .01$, it was not very large. In fact, many subjects did better using the nonpreferred hand than other subjects using the preferred hand, indicating sizable differences among subjects in terms of overall skill at the pegboard task. The experiment described in Example 1 controlled these differences by testing each subject under both conditions. This procedure made it possible to detect a rather small difference between the two experimental conditions, in their effects upon behavior. A procedure that did not control these differences in overall skill would be less precise, and might not detect the difference between performance with the preferred hand and performance with the nonpreferred hand. In other words, H_0 might in fact be false, but a less precise experiment might not allow us to reject H_0. To illustrate this point, along with the rank test, let us suppose that the data presented in Example 1 were collected by testing each subject under one condition only. That is, suppose the data had been gathered by testing one group of 15 subjects with the preferred hand, and a separate group of 15 with the nonpreferred hand.

Group using preferred hand		Group using nonpreferred hand	
Seconds	Rank	Seconds	Rank
11	1.5	12	3
11	1.5	14	5
14	5	17	10
14	5	18	12.5
15	7	19	15
16	8	19	15
17	10	21	18.5
17	10	22	20
18	12.5	23	22
19	15	23	22
20	17	28	26
21	18.5	28	26
23	22	28	26
27	24	30	28
36	29	38	30
Sum:	186.0	Sum:	279.0

There is a simple way of checking the total sum of ranks. If X is the total number of scores, then the total sum of ranks must equal $X(X + 1)/2$. Here, $186 + 279 = 30(31)/2$.

According to H_0, neither group ranks higher than the other. Applying the rank test:

Number of subjects in each group	15
N	15
R	186

Consulting Table 9 for $N = 15$, we see that H_0 may be rejected at the .05 level if R is 185 or less. In our experiment $R = 186$. Conclusion: Do not reject H_0 at $\alpha = .05$. By testing each subject under just one of the two conditions, we have not controlled individual differences in overall skill as well as we might, had we tested each subject under both conditions. We have failed to reject a H_0 which would have been rejected by a more precise experiment.

Exercise 3: A left-handed investigator has noticed that much of the world seems to have been designed for the convenience of right-handed rather than left-handed people. As a consequence, left-handed people have a greater opportunity than right-handed people to become skilled in using the nonpreferred hand. To test his hypothesis he gives the pegboard test to 10 left-handed subjects (Group L) and 10 right-handed subjects (Group R). Each subject tákes the test twice: first with one hand, then the other. For half of each group the first test is done with the preferred hand, the second with the nonpreferred hand (Order PN). The other half of each group does the first test with the nonpreferred hand, the second with the preferred hand (Order NP). The dependent variable is the time required to complete the task. The results:

Group	Order	Subject No.	Time (seconds) using	
			Preferred hand	Nonpreferred hand
L	PN	1	9	17
		2	12	16
		3	17	23
		4	15	18
		5	14	18
	NP	6	11	21
		7	10	18
		8	13	15
		9	12	24
		10	8	17
R	PN	11	10	21
		12	18	27
		13	13	26
		14	14	28
		15	9	19
	NP	16	13	21
		17	17	25
		18	16	27
		19	11	24
		20	12	28

Use appropriate descriptive statistics and appropriate statistical tests to answer the following questions: (1) Did the left-handed subjects perform significantly better with the nonpreferred hand than right-handed subjects? (2) Did the subjects do significantly better with the preferred hand than the nonpreferred hand? (3) Were the two groups equally skilled in the use of the preferred hand? (4) Did practice with the preferred hand facilitate performance with the nonpreferred hand? (5) In the present context "ambidextrous" means using both hands with equal facility. Were the left-handed subjects more nearly ambidextrous than the right-handed subjects?

Table 8

Table of the Binomial Test

Number of observations (N)	$\alpha = .10$	$\alpha = .05$	$\alpha = .01$
6	6	6	–
7	7	7	–
8	8	8	8
9	8	8	9
10	9	9	10
11	9	10	11
12	10	10	11
13	10	11	12
14	11	12	13
15	12	12	13
16	12	13	14
17	13	13	15
18	13	14	15
19	14	15	16
20	15	15	17
21	15	16	17
22	16	17	18
23	16	17	18
24	17	18	19
25	18	18	20
26	18	19	21
27	19	20	21
28	19	20	22
29	20	21	22
30	20	21	23

Table 9

Table of the Rank Test with *N* in Each Group

N	$\alpha = .10$	$\alpha = .05$	$\alpha = .01$
5	19	18	15
6	28	27	23
7	39	37	32
8	52	49	44
9	66	63	56
10	82	79	71
11	100	97	87
12	120	116	105
13	142	137	125
14	166	160	147
15	192	185	170
16	219	212	196
17	249	241	223
18	280	271	252
19	313	303	282
20	348	338	315

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APPENDIX

B USE OF THE RANDOM NUMBER TABLE

Under a variety of circumstances an experimenter must decide on some method for assigning items that are important in his experiment. These items may be subjects that must be assigned to groups, stimuli that must be arranged in sequences, various experimental conditions, or the like. Such problems may seem simple and straightforward, but unless he takes appropriate precautions, the experimenter may permit biases to creep into his procedure. Many sources of bias are subtle and insidious and may pass completely unrecognized by those concerned with the research. Among these, you should be aware of at least two: First, there is the so-called "natural selection" bias, which may lead the experimenter to select certain types of subjects before he chooses other. For example, if an experimenter wishes to pick one of two rats kept in the same cage, his first "catch" will almost inevitably be the less frightened and more docile one. In selecting subjects from a class, one finds, obviously, that the more eager and willing subjects will be the first to volunteer. Students free early in a semester may differ considerably from those who are free near the end of the semester. Second, there is the experimenter bias, which may "unconsciously" lead someone carrying out an experiment designed for confirmation of a particular hypothesis to assign the subjects in such a way as to bring out a "right" result.

An experimenter might offer a variety of testimonials to persuade the reader that he really did not allow his choices to be biased, but it turns out to be simpler and more convincing if he simply reports that his assignment to groups was by a particular one of the standard and widely accepted methods. These methods offer more than "reassurance" value. For example, they require that the experimenter prepare some sort of roster of the subjects. This increases the likelihood that he will recognize the population from which his subjects are a sample. Even more important, the methods ensure that one will meet a fundamental assumption underlying all statistical tests for differences between groups: the subjects be assigned in a random fashion—that is, that each subject have an equal likelihood of being assigned to any one of the groups.

There are many procedures available that meet the necessary requirements. For example, subjects could be divided into two groups by tosses of a coin, with all heads assigned to one group and all the tails to the other. A larger number of groups could be formed by tosses of a die, with the various numbers representing different groups. Or one could use a shuffled deck of cards, with the groups represented by suits or numbers. However, for careful researchers the simplest and most widely used method of group assignment makes use of a table of random numbers. Such a table is found in your manual on pages 202 and 203.

One may not realize the care that goes into the construction of published tables of random numbers. For example, one such table was made by squaring nine-digit numbers in an IBM computer, selecting and recording the middle five digits of the number, and then squaring the first nine digits of the large number, which in turn by a similar procedure yielded the next five-digit number of the table. After such a table has been tentatively recorded, extensive statistical tests are run to detect too frequent or infrequent occurrences of any digits, and to examine the frequency of "runs" of numbers.

A table of random numbers that survives the above tests is equally "random" when one uses only first digits or last digits of recorded numbers, whether one proceeds through rows or through columns, whether one chooses every other number, or proceeds backward or forward. Any consistent procedure will yield a random sequence of numbers. One must take care, however, not always to start at the same point in the table. Since our table has 40 rows and 20 columns, an experimenter might ask one friend to select a number between one and 40 and another to select a number between one and twenty and then start at a point indicated by those two numbers.

The first step in any assignment procedure is to prepare a complete list of the subjects. Next, the experimenter must decide on what restrictions he will impose in the assignment of the subjects. (One common restriction which leads to greater statistical convenience is that there be equal numbers of subjects in each of the groups.) Then the experimenter must decide on just how he will "read" and interpret the numbers in the table. For example, if an experimenter wished to assign the first ten letters of the alphabet to two experimental groups he might proceed as follows: He might begin at row 30, column three of the table and consider the odd numbers to represent group one and even numbers, group two. Reading across the row he finds the numbers 1, 5, 6, 5, 1, 7, 5, and so on. Subject A then would be assigned to group one, B to group one, C to group two, D, as well as the next four, E, F, G and H, to group one, and the next two to groups two and one, respectively. Checking back over his list the experimenter would find that the subjects C and I, would be in group two and that all the remaining subjects would be in group one. This is a perfectly acceptable procedure for assigning subjects without the restriction of equal numbers in the groups. Let us assume, however, that for perfectly legitimate reasons he wanted to divide the ten subjects into two groups of five. He might proceed as follows: selecting row 16, column five for his starting point, he might assign the first five numbers found in the table to group one. The first, subject number one, or A, would be assigned to group one as would the second, subject number five, or E, and the third, seven, or G. The next number to appear in the table is a five; but since five has already been assigned, that number is ignored. The next number, six, subject F, and similarly, three, or C would be placed in group one. Group one would then be composed of subjects A, C, E, F, and G, while group two would be composed of the remaining subjects, B, D, H, I, and J.

The assignment of 15 subjects to three equal groups presents a slightly more difficult problem. If we assign the first 15 letters of the alphabet, beginning, for example, at line two, column three in the table, we find that the first entry is 26. Since there are only 15 items to be assigned, we may ignore that number. The next number, 07, is assigned to group one. We ignore the 28 and assign 08, likewise, to group one. Then we pass all numbers until we reach 03, which is also assigned to group one. The remaining numbers in the line are ignored, as well as all in line three, including 07 because that has already been assigned. Thus we pass to 11 and then to 13. Group one, therefore, is composed of C, G, H, K, and M. Now we proceed in a similar manner, finding group two is composed of F, I, J, N, and O. The remaining items, A, B, D, E, and L consitute group three. This method of omitting numbers is acceptable when one has a sufficiently large table of random numbers. If one wishes to avoid this inexpensive waste, however, one may formulate a rule that will permit use of most of the omitted numbers. For example, one could subtract multiples of 15 from each number, which would make a 5 of 20, a 10 of 40, and 6 of 66, etc.

If one questions the legitimacy of selecting first one group and then another, one has but to examine the probabilities. One might ask whether the probability of being selected in the second of three groups is not, in fact, one-half. Since the probability of selection in group one in the above example is one-half, the probability of not being selected is two-thirds. Since group two is selected by choosing half of the subjects remaining after the selection of group one, the probability of being in group two is the probability of not being selected in group one, and also of being selected in group two. The probability of the former is two-thirds, and of the latter, one-half. Hence the probability of being selected in group two is two-thirds times one-half or one-third. Then, if the probability of selection in group one is one-third, and the probability of selection in group two is one-third, this means that the probability of selection in group three is one minus one-third plus one third, which is one-third. One may work out the probabilities for assignment to any number of groups in a similar manner.

Table 10

	1	2	3	4	5	6	7	8	9	10
1	73	78	83	37	20	64	26	27	72	28
2	52	38	26	07	28	08	79	36	88	44
3	39	16	32	65	56	49	74	42	43	07
4	55	63	02	19	86	86	95	27	33	81
5	34	09	42	44	69	08	95	44	93	21
6	43	13	45	78	72	47	46	30	64	58
7	88	59	15	68	94	96	74	73	58	51
8	59	88	57	62	54	00	30	39	90	45
9	54	63	38	98	64	18	13	21	59	97
10	08	80	15	33	93	88	33	10	23	29
11	71	48	39	84	08	14	42	03	94	88
12	69	47	79	48	36	81	66	28	11	13
13	43	39	40	97	27	70	85	73	23	99
14	13	31	91	61	22	54	51	45	83	29
15	14	35	65	78	05	89	20	43	26	22
16	41	43	99	73	15	75	63	09	93	60
17	79	24	16	46	50	59	05	05	81	15
18	94	05	25	70	32	06	49	19	58	87
19	85	74	17	98	59	07	33	48	77	63
20	19	73	77	26	56	21	62	65	88	52
21	25	12	76	83	74	05	65	56	38	94
22	99	47	97	71	26	61	98	76	10	44
23	65	09	80	06	32	75	72	10	03	77
24	95	96	87	51	59	81	85	90	06	03
25	70	96	10	30	86	47	48	98	58	12
26	76	65	23	10	53	75	73	14	10	14
27	64	57	39	78	27	67	54	34	47	51
28	72	99	61	29	04	71	71	73	96	05
29	86	59	79	54	65	29	52	33	83	49
30	41	43	15	65	17	57	05	86	84	95
31	33	75	74	85	85	10	01	95	25	58
32	47	33	79	41	53	52	59	26	87	31
33	42	24	39	43	07	66	03	12	23	76
34	74	59	35	18	57	19	84	73	74	92
35	06	77	09	60	80	44	35	66	55	96
36	17	51	05	04	60	46	06	59	90	07
37	82	09	73	72	39	27	03	50	44	05
38	75	57	57	78	28	05	13	77	11	81
39	66	91	92	72	65	40	70	83	54	47
40	24	87	35	60	34	46	32	66	65	23

Table of Random Numbers

11	12	13	14	15	16	17	18	19	20
68	28	33	12	89	26	81	16	02	38
95	35	77	94	03	71	85	89	30	86
98	28	34	67	11	54	13	36	49	91
71	58	95	55	86	35	74	13	32	57
78	59	35	65	30	26	76	06	60	69
47	00	37	77	17	09	38	64	38	94
55	88	78	42	76	81	35	57	06	85
65	78	63	97	28	66	91	63	65	17
49	66	49	51	55	24	96	67	09	40
52	58	71	30	46	79	95	34	42	21
06	23	74	07	18	84	07	55	21	80
21	38	06	80	46	20	21	86	63	07
81	22	84	72	19	82	31	71	32	25
18	02	65	81	41	46	18	78	66	21
38	67	70	79	22	41	67	03	65	56
23	74	12	47	33	84	38	36	36	94
22	76	90	04	65	55	48	69	69	14
41	27	45	91	20	21	56	11	22	96
73	42	12	50	51	81	12	98	66	72
84	65	04	85	14	15	04	20	78	68
59	83	01	39	56	69	99	38	41	99
33	81	38	43	90	09	63	63	62	55
21	86	12	06	06	31	59	03	02	33
47	09	21	56	04	11	27	30	07	44
89	39	59	18	73	06	85	13	01	17
66	62	58	73	46	54	98	67	77	65
02	33	16	02	20	77	86	18	39	11
64	79	46	90	63	65	49	31	54	29
93	73	28	52	42	58	02	62	73	88
82	40	69	50	73	04	13	51	19	69
63	92	99	54	83	48	17	37	29	27
77	46	92	61	22	27	80	49	27	60
89	18	71	64	31	99	96	89	22	26
78	64	08	83	04	58	72	72	45	72
73	67	39	07	86	15	10	56	05	27
27	25	58	92	41	30	47	90	30	88
56	02	32	77	07	62	13	51	46	52
77	54	13	49	12	69	69	68	94	91
98	12	77	99	33	94	68	70	70	16
54	47	95	10	16	52	79	60	57	20

APPENDIX

C EXPERIMENTAL REPORTS

An experimenter who completes an experiment in most instances arrives at some conclusion concerning the topic of his investigation. It is then necessary for him to report his research to fellow scientists and to make a statement of his conclusion. Such a report is in the form of a rather specialized type of argument. It is important, then, that students examine the details of the type of argumentation which will have an impact on appropriately skeptical readers.

In a report, a scientist explains why he carried out his experiment and then reconstructs the incidents and logic which brought him to his own conclusion. A successful report leads the reader to the same conclusion as that reached by the experimenter. When one realizes that the conclusions from experiments are the working propositions in science, it becomes obvious that chaos would result if each scientist drew his conclusions according to personal whim, and consequently functioned according to a highly personal list of these propositions.

A poor report will waste not only the writer's efforts spent in preparation of the report, but probably also the experiment itself. The potential reader may conceivably never read beyond the first few lines or paragraphs. Or worse, he may waste his time reading through the report and still be uncertain about how the experiment was run. In each of these cases the conclusion of the experiment will not be entered in the reader's active list of propositions. Someone else may eventually find it necessary to rerun the small experiment.

ORGANIZATION OF REPORTS

A typical outline for a report follows. The student must understand the objectives of report writing, and must check each section of the report to ascertain whether it has made its contribution to the argument being presented.

Few experienced report writers are able to write final reports in the first draft. A student should plan to write, evaluate, and rewrite until he achieves a worthy final product.

A typical experimental report must describe how the experimenter proceeded through the stages of his experiment. In most cases a journal article consists of a title and five major sections (Introduction, Methods, Results, Discussion, and Summary).

The title is not a sentence but is, nevertheless, a brief description of the nature of the experiment. Typically the title describes, in very specific terms, the independent and dependent variables. For example:

> The Effect of Varying Amounts of Alcoholic Consumption on the Ability to Maintain a Stylus on a Moving Target

Examples of other titles are:

> Changes in I.Q. Produced by Three Different Diets
>
> Nonsense Syllable Learning Following Different Amounts of Sleep Deprivation

Introduction

Every experimental study begins with some practical or theoretical problem. An experimental hypothesis is formulated. This is a guessed or predicted relationship between two variables. It may arise from curiosity about some natural process. It may follow from previous research by the experimenter. It may be a prediction from a formal theory. Whatever its origin, it must be possible to test the hypothesis. Some hypotheses are not testable on logical grounds. Their statement includes a denial of the possibility of empirical test. These are not properly the concern of the scientist. Other hypotheses are not testable at the present time because of inadequate technical skills. The scientist reserves judgment on such problems until means are developed for testing them.

The introduction has two purposes: (1) To describe the history, theory, and research relevant to the study; to show what led up to this study, *why the experimenter is doing it.* (2) To state the problem being investigated. With good writing, these two aspects will be well organized, i.e., the statement of the problem will follow naturally from the background leading up to this problem.

Method

Subjects. The experimenter must provide for an appropriate sample of subjects. Determination of the reliability of the experiment requires repetition of observations. In cases where a limited number of observations can be made on a given subject, reliability will be estimated from observations made on a number of subjects. The method of selecting subjects will determine in part the generality of the results obtained. Conclusions will be limited by considerations of the population from which the subjects came. In this section, one describes who the *S*s were, how many there were, and any other details that might be relevant. For example, in the alcohol experiment, one might write: Two hundred male undergraduates from Indiana University were used in this study. The subjects (*S*s) selected met two criteria: they had had no previous experience with a pursuit rotor, and in an earlier interview they had indicated that they were not habitual drinkers, i.e., they drank less than 1 "shot" (5 ml.) of alcohol per day.

Apparatus. Observation of the dependent variable sometimes requires apparatus. The galvanic skin response, for instance, involving changes in the electrical resistance of the skin, requires a galvanometer for its detection. The use of apparatus for recording behavior not only furnishes a permanent record of a subject's responses, but it is automatic and thus objective. Other devices may be used to manipulate the independent variable or control extraneous variables. One should describe in detail all materials and apparatus used in the experiment. In the drinking experiment the liquor used (e.g., "Old Crow bourbon whiskey, 86 proof served as the . . .") as well as the characteristics of the pursuit rotor would be described. If you perform experiments involving the sorting of cards, you will want to describe these cards in detail.

Procedure. The order of events scheduled to occur must be carefully worked out in advance, except in exploratory experiments. In the case of repetition of observations for the purpose of determining reliability, all conditions must be duplicated in detail. In writing this section, describe how the subjects were divided into groups. For example: The 200 *S*s randomly divided into 10 groups of 20 *S*s each. All *S*s in a given group received the same amount of alcohol. The 10 groups received 0, 5, 10, 15, 20, 25, 30, 40, or 45 ml. of alcohol. Then describe the step-by-step procedure that the *S*s went through.

Results

In this section the experimenter (*E*) describes in language the important results. Interpretations of these results come later (in the Discussion). Tables and graphs are used primarily to illustrate and clarify the verbal description. This description has three main functions:

1. It gives continuity to the report. Thus, one may repeat information that is also in tables and graphs, just to give a continuous organization to the report.
2. It draws the reader's attention to important details, which will be discussed later (e.g., "note in Fig. 3 that the downward trend is reversed after the fifth trial but begins again on the eighth trial").

3. It describes any statistical test that is applied and gives the outcome. Mention whether the null hypothesis could or could not be rejected (e.g., "The hypothesis that there was no effect from . . . was (not) rejected").

Tables have a table number, a title, or a legend that defines the numbers and abbreviations employed, and the table proper (or grid). A typical example is given.

Table 1

Mean Time-on-Target Scores in Seconds for the 10 Groups during 10 One-Minute Trials

Amount of alcohol consumed (ml.)	Trials				Total	Mean
	1	2	. . . . .	10		
0	55	57	. . . . .	60	575	57.5
5	40	42	. . . . .	58	402	40.2
.						.
.						.
.						.
.						.
.						.
45	20	22	. . . . .	40	315	31.5

Figures have a figure number, a legend, and the figure proper (often a graph). Two examples of figures are given below. Note that the axes are always labeled.

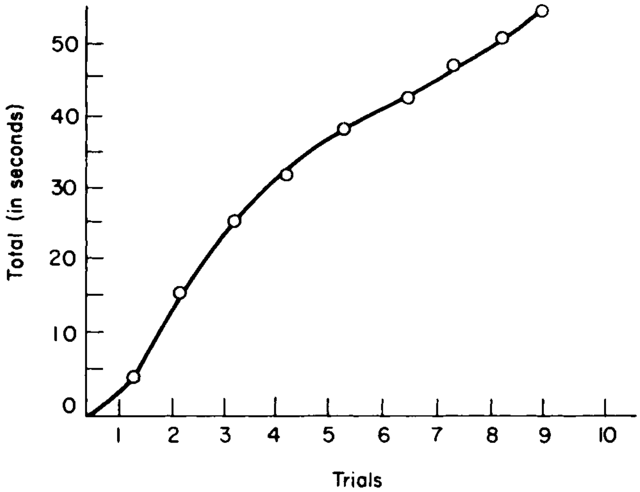

Fig 3 Time-on-target (TOT) scores during the 10 trials for the group receiving 10 ml of alcohol.

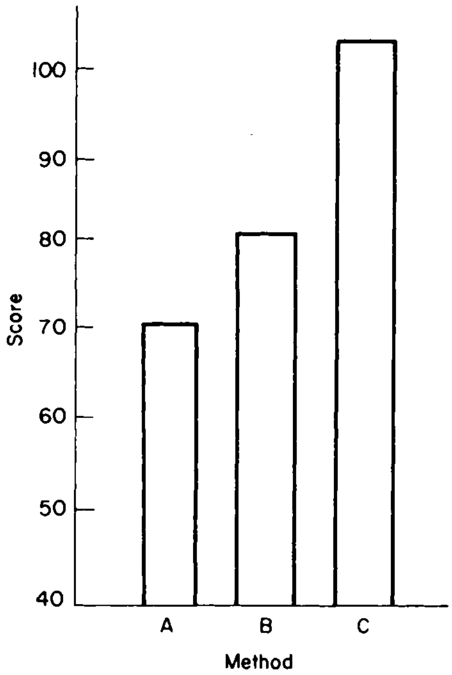

Fig 7 Mean final examination score for the three groups receiving different teaching methods.

Discussion

This section does not contain graphs or tables. It is straight prose which covers any or all (usually all) of the following topics:

1. Interpretation of the results. All the points should be discussed that the reader was asked to notice in the Results section as well as the outcome of any statistical test performed. Note that rejecting the null hypothesis will lead to a different discussion than retaining it.

2. Relation of the results to the problems, theoretical controversies, and earlier findings described in the Introduction. If the problems and controversies are not settled by the experiment, the reasons why should be given and further, or better, experiments should be suggested.

3. Statement of the experimenter's conclusions.

Summary

This should not exceed 250 words (it is typically less) and should include the statement of the problem, a minimum description of the subjects, apparatus, and procedure, the most important results, and the most important conclusions. In many reports, an abstract at the beginning of the paper is used instead of a summary.

GENERAL COMMENTS

1. All narrative (anything specific that was done or was observed) is put in the past tense. Certain general propositions, however, do not refer to specific historical occurrences, but are timeless and true; "This hypothesis implies that . . . " or "Figure 6 shows that . . . . "

2. The use of "I" or "we" is to be avoided. A scientific paper is not about the experimenter, but about what he has done and what he has found.

Bad: "We presented three sets of trials . . . . "
Better: "Three sets of trials were presented . . . . "
or
"The experimenter presented three sets of trials."

3. Ordinary, grammatical English sentences should be used throughout—exceptions are the title and table and figure legends. The writing should be as simple and specific as possible.

SAMPLE EXPERIMENTAL REPORT

Extinction and Spontaneous Recovery

(Abstract)

Thirsty rats trained to press a bar for water, then extinguished in two sessions, showed a significant increase in responding between the end of the first, and the beginning of the second session. The results were interpreted in terms of spontaneous recovery of a conditioned operant response. An alternative motivational interpretation was discussed.

INTRODUCTION

Experimental extinction does not seem to destroy a classically conditioned response, since the response will recur following a rest period (Hilgard & Atkinson, 1967, pp. 273-276). This return of the response as a result of rest is called spontaneous recovery. The purpose of this experiment was to demonstrate the spontaneous recovery of a conditioned operant response. Thirsty rats, trained to press a bar for water, received two extinction sessions spaced one to two days apart. Spontaneous recovery was defined as an increase in responding between the last part of the first session of extinction, and the first part of the second session.

METHOD

Subjects

The *S*s were 23 male albino rats, approximately 90 days old when the experiment began.

Apparatus

The operant conditioning box was 8 in. high, 8 in. wide, and 12 in. long. One end wall was fitted with a water tank and a manually operated dipper. The dipper mechanism produced a clearly audible click, and presented *S* with a drop of water as a reinforcement. An L-shaped bar projected through an opening in a side wall near the dipper. The end of the bar traveled downward about 1/2 in. and was returned to its original position by a counterweight attached to the other end.

Procedure

For several days prior to the experiment the *S*s were handled 5 min. daily, and were watered 1 hr. each day, with food continuously available. Each *S* was then habituated to the apparatus, trained to drink from the dipper, and trained to press the bar for water on a continuous reinforcement schedule.

After the response was well established, 50 additional responses were reinforced, and *S* was then extinguished for at least 20 min., and until no responses were emitted for five consecutive minutes. One to two days later, *S* was returned to the apparatus for a second, 5-min. extinction session as a test for spontaneous recovery.

Conditioning and extinction sessions began at approximately 21.5 hr. of water deprivation. Beginning with the last 50 reinforced responses, *E* recorded the number of responses emitted during each 1-min. interval.

RESULTS

Twenty of the 23 *S*s emitted more responses during the first 5 min. of the second extinction session than the last 5 min. of the first extinction session ($\alpha < .01$ by the binomial test), the means being 6 and 0 responses, respectively.

DISCUSSION

The *S*s in this experiment showed a highly reliable increase in responding between the two extinction sessions. If the increase could be attributed to the intervening rest period, the results could be interpreted as a demonstration of the spontaneous recovery of a conditioned operant response. However, an alternative interpretation must be considered. In this experiment, the first extinction period took place immediately after *S* had received some 50 reinforcements, i.e., drinks of water. Consequently, it is conceivable that the reduction in bar-pressing during the first extinction session was due in part to a reduction in motivation. If *S* were more highly motivated during the second extinction session than the first, this alone could account for the increase in responding between the two sessions. In future experiments of this type, the effect of the rest period will be revealed more clearly if the training and extinction sessions are given on three separate days, providing a more nearly constant level of motivation during the first and second extinction sessions.

REFERENCE

Hilgard, E. R., & Atkinson, R. C. *Introduction to psychology.* New York: Harcourt, Brace, & World, 1967.

APPENDIX

D INSTRUCTIONS FOR EXPERIMENT 19

CONDITION I

PAYOFF SCHEDULE

What YOU get . . .

	If YOU say . . .	
	YES	NO
and the other player says . . . YES	5	6
NO	−10	−8

What the OTHER PLAYER gets . . .

	If YOU say . . .	
	YES	NO
and the other player says . . . YES	5	−10
NO	6	−8

SUBJECT'S INSTRUCTIONS

You have two response cards—on one card is the word "YES," and on the other card is the word "NO." When the referee says "O.K." you are to show the card that indicates your response. ONLY THE REFEREE IS TO LEARN WHAT YOUR RESPONSE IS—*DO NOT TALK AT ANY TIME.* You may respond with either a "YES" or a "NO" on each trial (a trial is signaled when the referee says "O.K.").

Your BEST STRATEGY is to respond so that both you and the other player get the maximum possible points on each trial. That is, you want to respond so both you and your partner earn as many points as possible. The referee will record your responses, and from this record the point totals can be figured according to the payoff schedule on the preceding page.

CONDITION II

PAYOFF SCHEDULE

What YOU get . . .

If YOU say . . .

and the other player says . . .	YES	NO
YES	5	6
NO	−10	−8

What the OTHER PLAYER gets . . .

If YOU say . . .

and the other player says . . .	YES	NO
YES	5	−10
NO	6	−8

SUBJECT'S INSTRUCTIONS

You have two response cards–on one card is the word "YES," and on the other card is the word "NO." When the referee says "O.K." you are to show the card that indicates your response. ONLY THE REFEREE IS TO LEARN WHAT YOUR RESPONSE IS–*DO NOT TALK AT ANY TIME.* You may respond with either a "YES" or a "NO" on each trial (a trial is signaled when the referee says "O.K.").

Your BEST STRATEGY is to respond so that you get maximum points on every trial because THE PERSON ACCUMULATING THE MOST POINTS WINS. That is, you want to respond so you yourself earn more points than any other player. The referee will record your responses, and from this record the point totals can be figured according to the payoff schedule at the top of this sheet.