Skinner

Chapter Two

SCOPE AND METHOD

The Direction of Inquiry

So far as scientific method is concerned, the system set up in the preceding chapter may be characterized as follows. It is positivistic. It confines itself to description rather than explanation. Its concepts are defined in terms of immediate observations and are not given local or physiological properties. A reflex is not an arc, a drive is not the state of a center, extinction is not the exhaustion of a physiological substance or state. Terms of this sort are used merely to bring together groups of observations, to state uniformities, and to express properties of behavior which transcend single instances. They are not hypotheses, in the sense of things to be proved or disproved, but convenient representations of things already known. As to hypotheses, the system does not require them —at least in the usual sense.

It is often objected that a positivistic system offers no incentive to experimentation. The hypothesis, even the bad hypothesis, is said to be justified by its effect in producing research (presumably even bad research), and it is held or implied that some such device is usually needed. This is an historical question about the motivation of human behavior. There are doubtless many men whose curiosity about nature is less than their curiosity about the accuracy of their guesses, but it may be noted that science does in fact progress without the aid of this kind of explanatory prophecy. Much can be claimed for the greater efficiency of the descriptive system, when it is once motivated.

Granted, however, that such a system does possess the requisite moving force, it may still be insisted that a merely descriptive science must be lacking in direction. A fact is a fact; and the positivistic system does not seem to prefer one to another. Hypotheses are declared to solve this problem by directing the choice of facts (what directs the choice of hypotheses is not often discussed),

and without them a distinction between the useful and the useless fact is said to be impossible. This is a narrow view of a descriptive science. The mere accumulation of uniformities is not a science at all. It is necessary to organize facts in such a way that a simple and convenient description can be given, and for this purpose a structure or system is required. The exigencies of a satisfactory system provide all the direction in the acquisition of facts that can be desired. Although natural history has set the pattern for the collection of isolated bits of curious behavior, there is no danger that a science of behavior will reach that level.

The research to be described in this volume has been dictated by the formulation of the system described in the preceding chapter, and the general direction of inquiry may be justified by appeal to the system in the following way. There is a lack of balance, at the present time, in favor of respondent as against operant behavior. This is explicable on historical grounds. The discovery of the stimulus as a controlling variable was the first great advance in reducing behavior to some kind of order—a discovery that naturally encouraged research in bringing to light stimulus-response relationships. The investigation of the lower reflexes which began with Marshall Hall and reached its height with Sherrington established the reflex as a valid concept and set the pattern for analogous research on higher behavior. Pavlov's discovery of the conditioned reflex of Type S emerged from the study of unconditioned alimentary respondents, and the greater part of the work on conditioning has kept to this type. The early contention that the concepts applicable to spinal respondents and to conditioned reflexes of Type S could be extended to behavior in general has delayed the investigation of operant behavior. There is, therefore, good reason to direct research toward obtaining a better balance between the two fields, especially since the greater part of the behavior of the intact organism is operant.

An important historical phase of the investigation of respondents was topographical. New reflexes were discovered and named. But with the extension of the field through the discovery of conditioning and the realization that reflexes could be endlessly multiplied, the isolation and naming of reflexes lost much of its importance. No comparable phase has tended to arise in the operant field. The general topography of operant behavior is not important, because most if not all specific operants are conditioned. I suggest that the dynamic properties of operant behavior may be studied with a single reflex (or at least with only as many as are needed to assure the general applicability of the results). If this is true, there should be no incentive to 'botanize.' The present work is accordingly confined to a single reflex—the behavior of pressing downward a horizontal bar or lever. The only topographical problem to be considered is the legitimacy of defining a response in terms of certain properties. This is the problem of a unit of behavior, discussed at the end of the preceding chapter, which extends in the present work principally to the field of discrimination and to the necessity of formulating a discrimination in terms of related reflexes. The problem may be treated conveniently with a single operant.

The principal problems in the field of behavior lie in the direction of the laws of reflex strength, and this is the chief burden of the following work. The remaining part of the field—the interaction of separate reflexes—I have felt could not (except for induction and chaining) be successfully investigated until the laws of strength applying to the single reflex were better known. The stage of combining two reflexes in order to observe the resultant behavior has not been reached. The formulation and classification of the kinds of operations inducing changes in strength are chiefly an observational rather than an experimental problem, but the quantitative study of the laws governing the relation between the operations and the changes is clearly experimental. The central problem of the book is the formulation of behavior, the treatment of which is intended to be reasonably exhaustive. The experimental work fills in the formulative framework so far as I have been able to perform the experiments up to the present time.

The order in which the dynamic laws are considered is determined by experimental convenience. The study of variables which are most easily held constant may conveniently be postponed in favor of an experimental attack upon the less tractable. Age, sexual cycles, and health affect reflex strength, but they may be made relatively unimportant by using healthy male organisms in the least rapidly changing part of their life span. Drugs and surgical techniques that affect strength may simply be avoided. Emotion can for the most part be eliminated by careful handling and adaptation to the apparatus and procedure. Drive and conditioning, then, remain as the two principal factors to be investigated.

They are perhaps of the same order of tractableness. Either may be held fairly constant when the other is being studied. Conditioning is taken up first in the following pages because there is more to say about it now. Such a plan of procedure does not imply that the untreated factors are not important in the description of behavior but simply that being assumed to be susceptible of control they may be left until a later stage of the investigation.

It should be clearly understood that this book is not a survey or summary of the literature on behavior. It avoids topographical exploration. In the chapter on conditioning I shall not review all the kinds of reflexes that have been conditioned; in the chapter on drive I shall not try to cite the available material on all drives; and so on. My concern is with the formulation of typical material only. If I fail to discuss any *kind* of process about which there is at the present time any reliable information, it will be a serious omission, but I shall deliberately pass over many important investigations which are topographically parallel to those mentioned. Perhaps I should say something about the almost exclusive use of my own experimental material in connection with operant behavior. There is no implication whatever that this is the only important work that has been done in the field, but simply that I have had little luck in finding relevant material elsewhere because of differences in basic formulations and their effect upon the choice of variables to be studied.

The Organism

In the broadest sense a science of behavior should be concerned with all kinds of organisms, but it is reasonable to limit oneself, at least in the beginning, to a single representative example. Through a certain anthropocentricity of interests we are likely to choose an organism as similar to man as is consistent with experimental convenience and control. The organism used here is the white rat. It differs from man in its sensory equipment (especially in its poorer vision), in its reactive capacities (as of hands, larynx, and so on), and in limitations in certain other capacities such as that for forming discriminations. It has the advantage over man of submitting to the experimental control of its drives and routine of living. There are other organisms differing less widely in capacity that would serve as well in this respect, such as the ape, dog, or cat, but the rat has the following added advantages. It is cheap and cheaply kept; it occupies very little laboratory space; and it is amazingly stable in the face of long and difficult treatment. Some of the procedures to be described later could not have been used with dogs or apes because of the tendency of such organisms to develop 'neuroses' (64, 59). The rat is also easily adapted to confinement and has an advantage in this respect, especially over the cat. This does not mean that a result obtained with a rat is not applicable to a cat, but that the cat possesses strong reflexes conflicting with a particular experimental procedure which are weak or lacking in the case of the rat. Confinement is used as a means of excluding extraneous stimuli, and it is well to choose an organism for which this exclusion is as simply arranged as possible.

The rats used in the following experiments were in part members of a long inbred strain of albinos and an inbred hooded strain,[1] and in part commercial albinos of unidentified stock. With a very few exceptions all were males. Experimentation was usually begun at about 100 days of age. Experimental groups were practically always made up of litter mates. The rats were healthy at the beginning of the experiments and were discarded if any illness developed.

The Operant

The operant that I have used is the behavior of pressing downward a small lever. A typical lever is made of ⅛-inch brass rod and is shown in its place in the apparatus in Figure 1. The part available to the rat is a horizontal section 8 cm. long parallel to and approximately 1 cm. from the wall of the experimental box and 8 to 10 cm. above the floor. In order to press the lever down the rat must lift its forelegs from the floor, put one or both of them on the bar, and press downward with about 10 grams of pressure. The vertical movement of the bar is through a distance of about 1.5 cm.

The selection of this sample of operant behavior is based upon the following considerations.

(a) Either it is a practically universal unconditioned response (if it is to be regarded as unconditioned investigatory behavior) or it does not presuppose conditioned manipulatory behavior that is at all extraordinary for the species. Less than one per cent of the

[1] Kindly supplied by Dr. Gregory Pincus of the Harvard Biological Laboratories.

rats I have used have failed to make the response at some time or other.

(b) It has a convenient frequency of occurrence before conditioning takes place. An untrained rat placed in a small box with the lever will press it from one to ten or more times per hour, depending upon hunger, the presence of other stimuli, and so on. This is

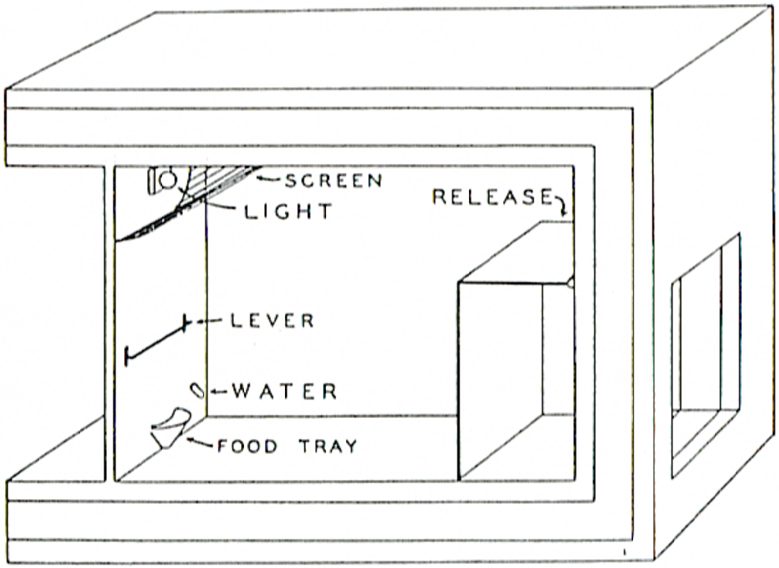

Figure 1

A Typical Experimental Box

One side has been cut away to show the part occupied by the animal. The space behind the panel at the left contains the rest of the lever, the food magazine, and other pieces of apparatus.

an adequate amount of 'spontaneous' activity for the conditioning of an operant.

(c) At the same time it does not occur so frequently without conditioning that the effect of reinforcement is obscured. In this respect it may be contrasted with running, lifting the fore part of the body into the air, and so on.

(d) It is not included in any other significant behavior. The response of flexing a foreleg, for example, might be a component part in the responses of scratching, eating, cleaning the face, running, climbing, and so on. A description of its changes in strength would need to take all these various behaviors into account. Two difficulties of this sort arise in the case of pressing a lever, but they may be eliminated in the following way. (1) The lever may be pressed when the rat is exploring the wall space above the lever, but this may be corrected by projecting the wall or a screen forward for a short distance above the lever (see the figure). (2) In certain types of experiments (involving an emotional reaction) the rat may gnaw the lever and incidentally move it up and down. When necessary this may be avoided by using a lever of larger diameter (say, 1.5 cm.) so that gnawing is either impossible or quickly discouraged.

(e) The response is relatively unambiguous. There is no difficulty in deciding whether or not a given movement is to be counted as an elicitation, as would be the case if the response were defined as a given movement of a leg, for example.

(f) It is made in approximately the same way upon each occasion. The differences actually observed will be discussed later.

(g) Lastly, the response requires external discriminative stimulation (provided by the lever). The nature of this will be considered later. Its presence is necessary for two reasons. If the response did not need what Tolman (71) calls external support, it might be made by the organism outside the experimental situation, but no record would be taken and no reinforcement provided. Experiments which extended over a number of experimental periods would be seriously disturbed. Secondly, the sample must be discriminative in order to be typical. It would be quite possible experimentally to use such an 'unsupported' response as flexing a leg or flicking the tail, but it is only in verbal behavior that such non-mechanically effective responses are reinforced (*i.e.*, when they become gestures). In general, a response must act upon the environment to produce its own reinforcement. Although the connection between the movement of the lever and reinforcement is in one sense artificial, it closely parallels the typical discriminated operant in the normal behavior of the rat.

The response of pressing a lever meets these several requirements with reasonable success and is perhaps nearly optimal in this respect. It does not follow that the laws arrived at in this case cannot be demonstrated with other kinds of responses. The analysis necessary for the demonstration would simply be more difficult.

For example, if the response were part of many different kinds of conditioned and unconditioned behavior [see (d), page 49], the curves obtained during various changes in strength would be composite and highly complex but not for that reason less lawful.

The reinforcement of the response is accomplished automatically with a food magazine which discharges pellets of food of uniform size into a tray immediately beneath the lever. The pellets are made with a device similar to a druggist's 'pill-machine' and are composed of the standard food with which the rats are normally fed. When the lever has been pressed and a pellet eaten, the rat is left in approximately the same position relative to the lever as at the beginning.

The entire behavior of lifting up the fore part of the body, pressing and releasing the lever, reaching into the tray, seizing the pellet of food, withdrawing from the tray, and eating the pellet is, of course, an extremely complex act. It is a chain of reflexes, which for experimental purposes must be analyzed into its component parts. The analysis is most easily carried out by observing the way in which the behavior is acquired. In describing material of this sort an abbreviated system of notation is practically indispensable, and I shall insert here a table of the symbols to be used, not only in this discussion, but during the course of the book.

A System of Notation

The symbols to be used and their definitions are as follows:

S = a stimulus

R = a response

$S . R$ = a respondent

$s . R$ = an operant (The originating force in an operant is specified in the formulation as s, although it is not under experimental control.)

The properties of a term are indicated with lower case letters. Thus, $Sabc$ . . . = a stimulus with the properties a, b, c . . . (wave-length, pattern, intensity . . .). The absence of a property is indicated with the corresponding Greek lower case letter. Thus $R\alpha$ = a response lacking the property a.

Superscripts comment upon the term, refer to its place in a formula, and so on, without specifying properties. Specific examples (to be defined later) are: S^r (a reinforcing stimulus), S^D (a discriminative stimulus correlated with reinforcement), and S^Δ (a discriminative stimulus negatively correlated with reinforcement).

A composite stimulus is indicated by juxtaposition of its parts without punctuation, as in $sS^{D\prime}S^{D\prime\prime}$.

When examples are given, they are inserted after the symbols with a separating colon, as in the expression *S : shock . R : flexion.*

[ ] = 'the strength of' the enclosed reflex. Thus, $[sS^D\lambda . R]$ will later be seen to represent 'the strength of an operant in the presence of a stimulus which is correlated with a reinforcement and is characterized as such by the absence of the property *l*.'

→ = 'is followed by.' For example, we may later use the expression $s . R\,a \rightarrow S^r$ for 'a response made without respect to discriminative stimulation which is reinforced provided it does not possess the property *a*.'

Analysis of the Chain

The Law of Chaining was stated in Chapter One in this way: the response of one reflex may produce the eliciting or discriminative stimulus of another. This is a principle of extraordinarily wide application in the integration of behavior. Most of the reflexes of the intact organism are parts of chains. The sample of behavior used here is typical in this respect, and its 'molecular' nature (71) must be carefully stated.

The later stages of the behavior of pressing the lever and eating the pellet are unconditioned respondents. A hungry rat will respond to the touch of food upon the lips by seizing the food with its teeth (and hands), chewing, moistening with saliva, and swallowing. The response of seizing the food in the mouth has been studied by Magnus (61). The behavior of chewing and swallowing may be analyzed into a rather intricate series of reflexes, which are of only slight interest here.[2] The chain is important in the study of behavior only up to the point of the seizing of food, which may be written *S : food . R : seizing.*

At the beginning of an experiment a hungry rat is placed in the experimental box containing the tray for several periods of, say, one hour. Investigatory responses to the walls of the box, the tray, and so on, are elicited but soon adapt out to a fairly low strength. The tray contains food, however, and certain movements made by the rat in the presence of stimulation from the tray and adjacent parts of the box are reinforced by the action of *S : food*. Such movements become fully conditioned and are made with considerable frequency by a hungry rat. The response is a discriminated operant, the nature of which will be more or less thoroughly investigated later. It may be written sS^D*: tray . R : approach to tray*. The chain stands at this point as follows:

sS^D*: tray . R : approach* → *S : food . R : seizing.*

The next step in building up the total sample is the establishment of a 'remote' discrimination (see Chapter Five), in which sS^D*: tray . R : approach* is reinforced only when a discriminative stimulus supplied by the sound of the food magazine is presented. The tray is empty except after the magazine has dropped a pellet of food into it. The rat comes to respond to the tray when the magazine sounds but not frequently otherwise. The reinforced reflex may be written sS^D*: tray* S^D*: sound . R : approach.* As will be shown in Chapter Six the sound of the magazine now acquires reinforcing power and a further member of the chain may be added, namely, pressing the lever, which produces the sound of the magazine because of the arrangement of the apparatus. The response to the lever depends upon discriminative stimulation supplied tactually by the lever itself and the reflex may be written

sS^D*: tactual lever . R : pressing.*

[2] Wright (79) lists the following steps in the case of human deglutition:

'1. After mastication, the food is rolled into a bolus and is moved to the back of the mouth by elevation of the front of the tongue. The mylohyoid contracts, and the bolus is thrown back between the pillars of the fauces.

'2. The sensory nerves at the entrance to the pharynx are stimulated, and reflexly through the medullary centres the following complex co-ordinated movement results:

i. The soft palate is elevated and the post-pharyngeal wall bulges forward to shut off the posterior nares.

ii. The posterior pillars of the fauces approximate to shut off the mouth cavity.

iii. The larynx is pulled up under cover of the root of the tongue, and the vocal cords are approximated.

iv. The epiglottis serves as a sloping ledge to guide the bolus past the laryngeal opening.

v. Respiration is inhibited.

vi. The superior constrictor muscles are relaxed to receive the bolus.

'3. A peristaltic wave propels the food along the oesophagus.'

A further link is added because the tactual stimulation from the lever reinforces all responses toward the lever which produce it. Such a response is also a discriminative operant, which may be written $_sS^D$: *visual lever* (*or stimulation from adjacent parts of the apparatus*) . *R*: *lifting hands and fore part of body*. The completed chain may be written:

> $_sS^D$: *visual lever* . *R*: *lifting* → $_sS^D$: *tactual lever* . *R*: *pressing* →.
> $_sS^D$: *tray* S^D: *sound of magazine* . *R*: *approach to tray* →
> *S*: *food* . *R*: *seizing*,

where the second arrow is understood to connect the response with S^D: *sound* only. Dropping out the names of the terms, numbering the parts, and omitting the discriminative stimulation supplied by the tray in the absence of the sound of the magazine, we have:

$$_sS^{D\,IV} . R^{IV} \rightarrow {_sS^{D\,III}} . R^{III} \rightarrow {_sS^{D\,II}} . R^{II} \rightarrow S^{I} . R^{I}$$

which represents the final structure of the behavior.

Of these four reflexes only Reflex III will be recorded and studied in what follows, but it is possible to give a fair account of the whole chain through this one member. Any occurrence of Reflex IV is almost invariably followed by Reflex III (if the lever is touched, it is pressed), and any occurrence of Reflex III implies the occurrence of Reflex IV (if the lever is pressed, it must have been touched). When the chaining is intact, Reflexes II and I practically always follow. The chaining is under experimental control, however, and the effect of breaking the chain will be studied in certain cases. The use of a chain cannot be avoided in dealing with operant behavior because the very act of reinforcement implies it. A simpler example, as I have said, could have been used by making Reflex III independent of external discriminative stimuli, for example, by using mere flexion of a limb, but it would have been less typical of the normal behavior of the organism.

Chaining is not peculiar to operant behavior. The example of swallowing described above (footnote, p. 52) is almost entirely respondent. Excellent examples of the analysis of chains of respondents are given by Magnus (61) in his work on posture and progression. The principle is the same, with the slight exception that in the case of operants the responses produce discriminative rather than eliciting stimuli.

In every case what we have is a chain of reflexes, not a 'chained

reflex.' The connections between parts are purely mechanical and may be broken at will. Any section of a chain may be elicited in isolation with the same properties which characterize it as part of the total chain. There is no reason to appeal to any unique property of the whole sample as an 'act.' I make these statements as explicitly as possible in view of prevailing opinions to the contrary. Experimental justification for the present 'molecular' view will accumulate during the rest of this work.

Control of Extraneous Factors

Whatever success the experiments to be described later may have in revealing uniformities in reflex strength is due to the procedures through which the reflex is isolated and through which extraneous factors affecting the strength are controlled. A first precaution is the removal of stimuli which elicit other reflexes, the necessity of which follows obviously enough from the formulation given in Chapter One. Not all such stimuli can be removed, but a nearly maximal isolation can be achieved by conducting the experiments in a sound-proof, dark, smooth-walled, and well-ventilated box, such as is shown in Figure 1. The stimuli that remain are chiefly the sounds produced by the rat's own movements and the tactual stimulation from the box. By placing the ceiling beyond reach of the rat one wall is effectually removed. The size of the base should be a compromise between a minimal size representing the smallest possible stimulating surface and a maximal size eliciting no responses to restraint. The boxes that I have used vary from 10 cm. x 20 cm. to 30 cm. x 35 cm. at the base. Reflexes in response to the walls and the incidental stimuli produced by the rat itself adapt out quickly, and the rat remains in a relatively inactive state until specific reflexes in response to the tray and lever are established. The ventilation of the box is achieved by drawing air out through a small tube not shown in the figure.

The control of the drive (in this case hunger) is not so easily arranged. For most purposes the same degree of drive must be reproduced upon successive days, and in many cases the degree must be varied in a known way. The use of different periods of fast is open to the objection that the organism does not eat continuously. If it were true that food is ingested at a stable (necessarily low) rate, it would be possible by cutting off the supply of food at different times before the experiment to obtain an array of degrees of hunger having some relation (not necessarily linear) to the lengths of fast. But the rat ordinarily confines its eating activity to a few periods during the day, and much depends upon the state of the organism just before the fast is begun. The method is valid only where the irregularity due to this factor does not matter, which means during fasts of the order of several days. These induce extreme degrees of hunger, which are complicated by other factors, and the method is inadequate for most purposes.

The feeding of limited amounts of food daily will also produce progressive changes in hunger unless the amounts are happily chosen. Modifying the amounts as the weight of the rat changes will avoid prolonged progressive changes but is probably too slow an adjustment to give a uniform hunger from day to day.

It has been possible to reproduce a given degree of drive upon successive days through the following procedure. The rat is placed on a schedule of daily feeding, according to which it is allowed to eat freely once a day for a definite length of time. With dry food a feeding period of one or two hours may be advisable; with a mash as little as ten minutes will suffice. The food I have used is a standard dog biscuit (Purina Dog Chow), which is capable of maintaining rats in good health for several months without a supplementary diet. After about a week of this procedure a high and essentially constant degree of hunger is reached each day just before the time of feeding. Proof of the constancy will be given in Chapters Four and Ten. From this essentially maximal value various lower states may be reached by feeding uniform amounts of food, as will also be shown later. Since thirst affects hunger, a supply of water is made available at all times. The 'hunger cycle' obtained in this way is a function of external stimuli which act as a sort of clock. It can be successfully maintained only if the living conditions of the rat are held constant. The cycle is also a function of the temperature and perhaps also of the humidity. In most of the present cases the rats remained between experiments in a dark sound-proof room at a temperature of from 75° to 80°, varying for any one experiment less than one degree. The humidity was not controlled.

The experiments are conducted at the usual feeding time in order to take advantage of the constancy of the peak of the cycle. When small amounts of food are used in the experiment, however, the major part of the daily ration must be given later, and this introduces a difficulty. If an experiment is repeated for several successive days, the peak of the cycle may shift from the beginning to the end of the experimental hour. Evidence for such a shift may be obtained independently from a study of the spontaneous activity of the rat (see Chapter Nine). In order to eliminate the shift, the experiments may be conducted on alternate days only, the animals being fed on the intervening days in their living-cages at the beginning of the hour of the experiment. In many of the experiments here described in which a process extended over a period of several days this procedure was used. The intervening days are neglected in the description, where such a phrase as 'the preceding day' is to be understood to mean the preceding experimental day, with an intervening non-experimental day omitted.

The elimination of extraneous stimuli has the added effect of avoiding most sources of emotional change. The principal precaution that must be taken is in the handling of the animals at the beginning of an experiment. The effects of handling may be minimized by confining the rat behind a release door when it is put into the experimental box and allowing it to remain there for a minute or two after the box is closed and before the experiment proper begins. The release door should be reasonably silent in operation and out of reach of the rat when open. The drawing in Figure 1 shows such a door in place. It is operated by a projection of the shaft upon which it is mounted and is held against the ceiling when open.

While I have never repeated experiments without precautions of this sort, I believe that the regularity of the data obtained testifies to their advisability.

The Measurement of the Behavior

The problem of recording behavior is in general easily solved. Compared with the data of many other sciences behavior is macroscopic and slow. A single moving picture camera will provide most of the required information in a convenient form, although a battery of cameras and a sound-recorder will, of course, do even better. But a mere record, in the sense of a portrait or representation, is not to be confused with measurement. No matter how complete, a representation is only the beginning of a science. What it does—

whether obtained with a system of notation or with photography and phonography—is to permit leisurely inspection and measurement. The most complete and accurate record of behavior possible would differ from the behavior itself only in that it could be run slowly, or held still, or repeated at will.

So far as measurement is concerned, much of the detail of a complete representation is unnecessary and even inconvenient. I am not speaking here of the wholesale measurement of behavior which yields a sort of quantified narrative but of measurement which presupposes an analytic and selective system. The need for quantification in the study of behavior is fairly widely understood, but it has frequently led to a sort of opportunism. The experimenter takes his measures where he can find them and is satisfied if they are quantitative even if they are trivial or irrelevant. Within a system exhibiting reasonable rigor the relative importance of data may be estimated and much useless measurement avoided. With a systematic formulation of behavior it is usually possible to know in advance what aspect of behavior is going to vary during a given process and what must, therefore, be measured. In the present case the following aspects of the system bear upon the problem of the measure to be taken: (1) the definition of behavior as that part of the activity of the organism which affects the external world; (2) the practical isolation of a unit of behavior; (3) the definition of a response as a class of events; and (4) the demonstration that the rate of responding is the principal measure of the strength of an operant. It follows that the main datum to be measured in the study of the dynamic laws of an operant is the length of time elapsing between a response and the response immediately preceding it or, in other words, the rate of responding.

It may be objected that information other than the rate could surely do no harm and might be interesting or even valuable. It is true that simultaneous photographic records would have been useful in perhaps one per cent of the following cases; beyond that, opposing practical considerations must be taken into account. By recording the rate of responding only, it has been possible for one person to study approximately two million responses within six years. With a few exceptions only one thing is known of each response—how long a period of time elapsed between it and the preceding response. This single datum is enough for the purpose of the present formulation, and the result is, I believe, more valua-

ble than a more complete description of a small part of the same material would have been.

The movement of the lever is recorded electrically as a graph of the total number of responses plotted against time. The required apparatus consists of a slow kymograph and a vertically moving writing point. At each response the point is moved a uniform distance by an electrically operated ratchet. A step-like line is

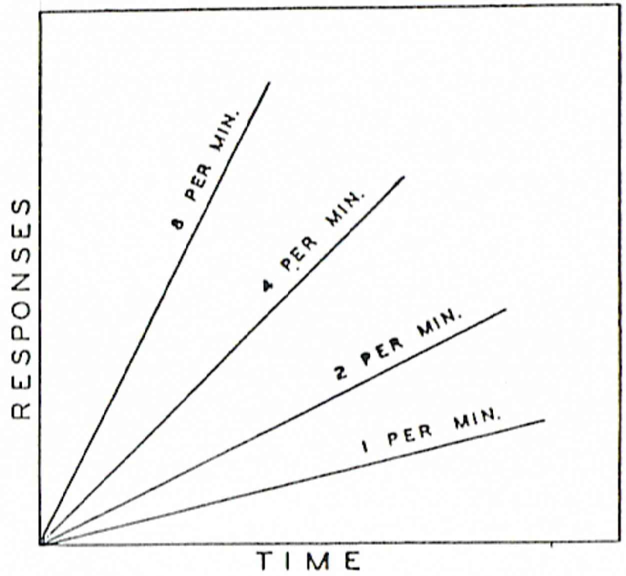

Figure 2

Sample Slopes Obtained with the Coordinates Most Frequently Used in the Following Chapters

The number of responses per minute represented by each slope is indicated. The actual records are step-like.

obtained, the slope of which is proportional to the rate of responding. The speed of the kymograph and the height of the step are chosen to give a convenient slope at the more frequent rates of responding. In Figure 2 some representative slopes are given for the coordinate values used in the greater part of the following account. The step-like character is not shown in the figure. [The movement of the lever operates the recorder by closing a mercury switch on the other side of the panel bearing the lever. In the first experiments with this method a needle attached to the lever-arm dipped into a small cup of mercury. When the lever was moved slowly there was a tendency for the contact to chatter, and this was corrected by inserting into the circuit to the recorder a device which made it impossible for a second contact to be recorded within, say, one second. It has been found that a commercial mercury tube switch does not require this precaution.]

With a record of this sort it is possible to survey at a glance the state of a reflex and its various changes in strength during an experimental period. The form of the record is especially adapted to the study of dynamic laws. We are often interested, it is true, in the course of the change in *rate* rather than in the total number of responses, but it is much easier to record the responses of the rat in a cumulative or integral curve than in a differential. When we are interested in the rate, the curves must be read with respect to their slopes. It is often convenient to have a plot showing rate against time, and examples are given in many cases below. I have not converted all records to this form, however, partly because I wish to remain as close to the experimental data as possible but also because the cumulative curve has a special advantage in dealing with the notion of a reserve and with its subsidiary effects (such as compensation for temporary deviations).

Records of this sort are easily classified and filed, and they supply a permanent first-hand account of the behavior. It may be noted that at no point does the experimenter intervene for purposes of interpretation. All the curves given in this book (except those obtained by averaging or those extending over a number of days) are photographic reproductions of records made directly by the rats themselves. The presence of the experimenter is not required after the experiment has begun. Many of the figures reproduced later were taken *in absentia*. Because of the automatic character of the apparatus it is possible to conduct several experiments simultaneously. I have usually worked with sets of four, although in certain cases as many as twelve animals have been studied at the same time.

Chapter Three

CONDITIONING AND EXTINCTION

The Process of Conditioning

'The term "conditioned" is becoming more and more generally employed, and I think its use is fully justified in that, compared with the inborn reflexes, these new reflexes actually do depend on very many conditions, both in their formation and in the maintenance of their physiological activity. Of course the terms "conditioned" and "unconditioned" could be replaced by others of arguably equal merit. Thus, for example, we might retain the term "inborn reflexes," and call the new type "acquired reflexes"; or call the former "species reflexes" since they are characteristic of the species, and the latter "individual reflexes" since they vary from animal to animal in a species, and even in the same animal at different times and under different conditions.'

This quotation from Pavlov [(64), p. 5] will serve to explain the use of the term 'conditioned.' It denotes a class of reflexes which are *conditional* upon a certain operation performed upon the organism (called reinforcement). The French term (*les réflexes conditionnels*) is in better accord with this meaning. A conditioned reflex may be identified as such by showing, not that it does not exist at birth (an unconditioned reflex may 'mature' later and a conditioned reflex develop earlier), but that it did not exist until the operation of reinforcement had been performed. It may also be distinguished by showing that through elicitation without reinforcement it is removed from the repertory of the organism.

The emphasis in the quotation upon a *kind* of reflex is unfortunate. Except for its dependence upon reinforcement the conditioned reflex behaves with respect to other operations just as any other reflex. The important thing is the process of conditioning and its reciprocal process of extinction. The changes in strength effected by reinforcement continue after the reflex has been acquired and after the distinction between innate and acquired has become